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THE BRITISH JOURNAL OF METALS

Vol. 51 No. 304 FEBRUARY, 1955 Monthly: TWO SHILLINGS

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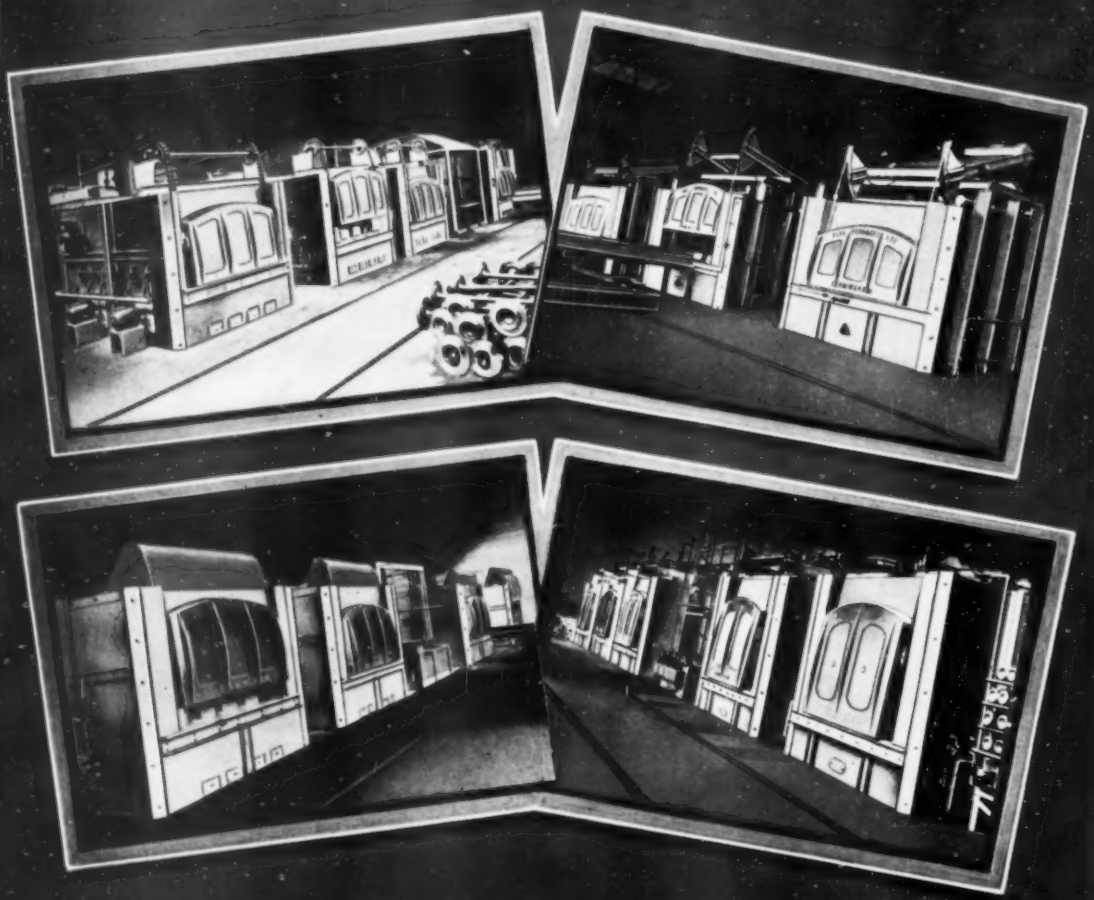

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INCORPORATING THE METALLURGICAL ENGINEER

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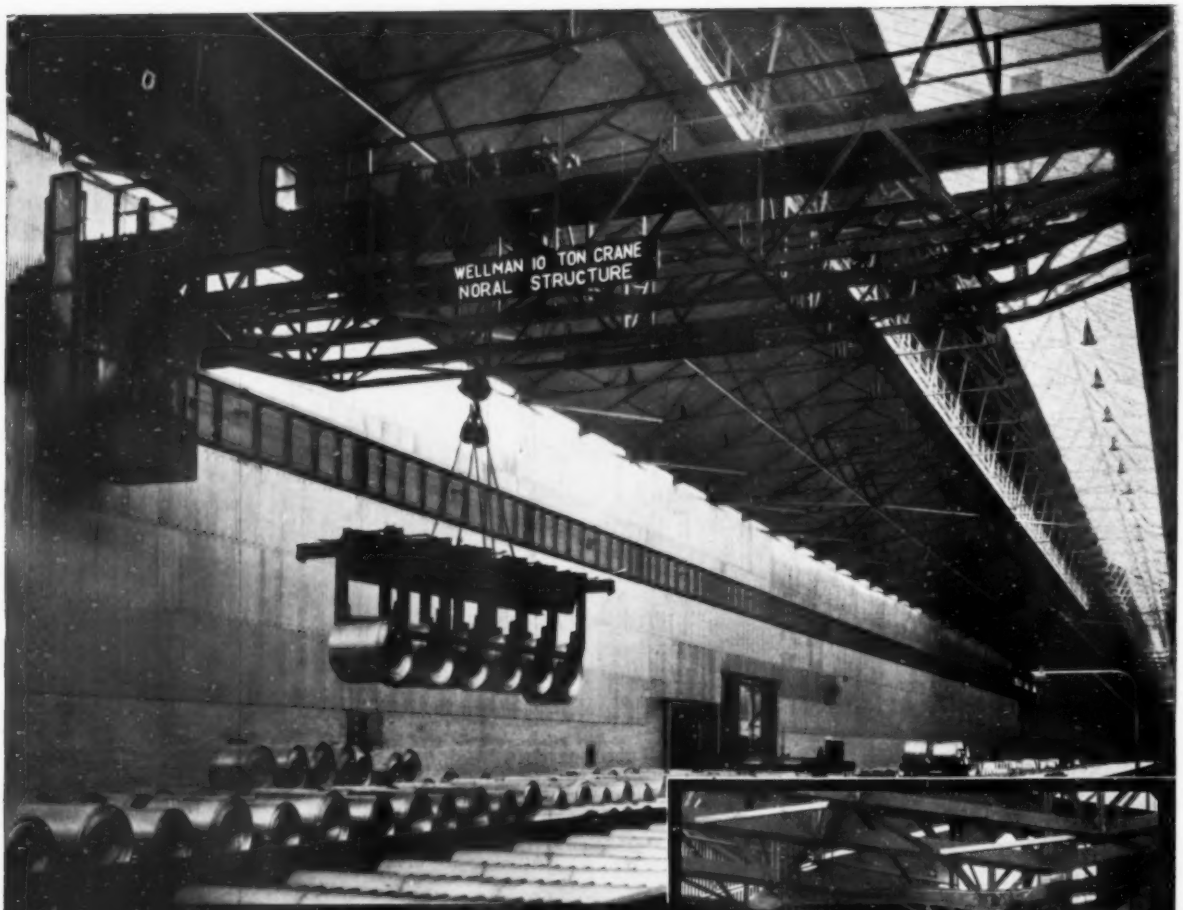

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

FEBRUARY, 1955 Vol. LI. No. 304

Specifications and Testing

IN a recent paper before the West of Scotland Iron and Steel Institute on "Acceptance Tests: What is Really Wanted?" Mr. J. M. Mowat put forward a strong plea for early consultation between designer and steelmaker so that a proper specification can be prepared to satisfy all requirements in the simplest and safest manner. This, and his appeal to designers to use "En" and such general specification groupings merely as a guide, and to go to the supplier with their problems, appears to cut across the attempts at standardisation which have been made with a view to reducing the number of specifications in use and so bringing down production costs. Mr. Mowat is, of course, concerned with the production of large forgings and castings, where the customer has fairly definite ideas of what he wants. In many cases, too, he knows enough about steelmaking to decide what he can reasonably expect to get. On the other hand, steelmakers—and this is not an exclusively ferrous phenomenon—sometimes receive orders containing requests which are either impracticable or quite unsuitable, and it was with this in mind that Mr. Mowat advised co-operation between customer and supplier at an early stage.

In all cases the designer's aim is to make the finished product sound and reliable, but in so doing he should bear in mind that to make a job better than it need be is not necessarily good engineering. We have always stressed the need for quality, but there is no point in "gilding the lily," whether appearance or strength is concerned. Moreover, in his desire to strengthen the job, the designer may be piling up trouble for those colleagues responsible for manufacturing the product. This is particularly true where welding may be necessary, as the difficulties of welding often increase with the tensile strength of the steel welded, although, for the same strength, some steels have better weldability than others.

For similar reasons the good designer should bear in mind such manufacturing operations as machining, forming, finishing, etc., and try to arrive at a compromise which will ensure the satisfactory functioning of the finished part with the least difficult and most economical method of manufacture. For the best results, therefore, there should be co-operation at the earliest possible opportunity between the designer, the production engineer and the metallurgist—even before an approach is made to the supplier—for the metallurgist should be able to make certain that the specification put forward is at least a reasonable one. Moreover, he is likely to know which suppliers can satisfy the requirements contained therein.

The idea of co-operation between designer and metallurgist is also advanced in a paper by three Battelle scientists which appeared in *Steel* last year. In their view the complexity of the materials picture is increasing as a result of continued development and of improvements resulting from research. Because a designer cannot be expected to be acquainted with all the latest material developments, some progressive U.S. concerns are taking the view that "two heads are better than one" and are setting up material selection committees on which close co-operation is possible between metallurgists, corrosion specialists, physicists, purchasing agents, production men and designers. Some remarks of H. W. Gillett may be quoted in this connection: "It is seldom that one individual is an expert in design, in metallurgy and in testing, and it is not desirable to take up the time of a good designing engineer to turn him into a poor metallurgist, or vice versa. There is too prevalent a desire among designers for a reference book to which they can turn for the way out of any particular dilemma in choice of materials, without bothering to think the matter out or to take counsel. This cookbook attitude is a dangerous one and should not be catered to."

Having decided what sort of material will satisfy the design and manufacturing sides, a draft specification should be drawn up to ensure that, with as little testing as possible, the material will meet the requirements of all concerned. "As little testing as possible" may, in fact, mean an extensive programme of work, but each item should be designed to check some particular property, or combination of properties, considered important to the project.

A specification having been prepared, it is essential that the correct attitude towards it should be adopted, namely, that it should be regarded as a means of passing material, not rejecting it. Suppliers must sometimes wonder, in the light of the attitude of some inspectors, whether the correct term is "acceptance tests" or "rejection tests." We hold no brief for the supplier who adopts an "its near enough" attitude, any more than we do for the inspector who says, without the slightest consideration, "it's 0·1 ton/sq. in. down on tensile strength—reject it." Any supplier who plays on the fact that his customer is reasonable and will use the material if it is at all possible, deserves any reversion to a strict insistence on the letter of the specification that may result.

There are almost as many variations on the "fools and wise men" saying as on the Prime Minister's famous "—so much . . . so many . . . so few" phrase, but at the risk of adding to them, it may truly be said that any fool can reject, but it takes a wise man to pass with safety something not quite up to specification. Sound judgment is called for, and nowhere is this more true than in the sphere of non-destructive testing, where, on the interpretation of the indications given by radiography, magnetic particle testing or ultrasonic exploration, the fate of the material may depend. No piece of material is perfect: as to how far from perfect it will be satisfactory is again a matter for co-operation between designer and metallurgist.

Meeting Diary

18th February

Institution of Chemical Engineers. "A New Technique for Particle Size Distribution Analysis by Centrifugal Sedimentation," by J. K. Donoghue and W. Bostock. College of Technology, Manchester. 7 p.m.

Manchester Association of Engineers. "Some Aspects of Drop Forging Practice," by K. Fidler. The Engineers' Club, Albert Square, Manchester. 6.45 p.m.

West of Scotland Iron and Steel Institute. "An Improvement in Hot-Top Design for Killed Steels" and "The Colville-Hamilton Ladle Metal Depth Indicator," by A. M. Hamilton. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

21st February

Institute of Metal Finishing (London Branch). "Surface Treatment of Steel in Relation to the Smoothness of Hard Chromium Deposits," by R. A. F. Hammond and W. A. Marshall. Northampton Polytechnic, St. John Street, London, E.C.1. 6.15 p.m.

22nd February

Institute of Welding (South Wales Branch). Paper on "Welded Ship Construction." Joint Meeting with the Institute of Marine Engineers. South Wales Institute of Engineers, Park Place, Cardiff. 7.15 p.m.

North East Metallurgical Society. "Plain Bearing Metals," by P. T. Holligan. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

23rd February

Manchester Metallurgical Society. "Brittle Fracture," by T. S. Robertson. Lecture Room, Central Library, Manchester. 6.30 p.m.

North East Coast Institution of Engineers and Shipbuilders. "Some Advances in Non-Marine Welding Technique," by J. Harbottle. Cleveland Scientific and Technical Institution, Middlesbrough. 6 p.m.

24th February

Institution of Engineering Inspection. (North-Western Branch.) "Quality Control," by E. Summerscales. The Engineers' Club, Albert Square, Manchester. 7.30 p.m.

25th February

Incorporated Plant Engineers (Birmingham Branch). "The Scientist and Non-Scientist in Industry," by Dr. J. H. Fremlin. University of Birmingham. 7.30 p.m.

Institute of Metal Finishing (Sheffield and N.E. Branch). "Some Aspects of Silver Plating," by R. R. Benham. Grand Hotel (Fitzwilliam Room), Sheffield. 6.30 p.m.

Institute of Welding (Birmingham Branch). "The Inspection and Testing of Welds," by A. H. Goodger. Birmingham and Midland Institute, Paradise Street, Birmingham, 1. 7.30 p.m.

Institute of Welding (South London Branch). "Fundamentals of Welding": "Fusion Welding," by V. W. Clack; "Resistance Welding," by H. E. Dixon. Kingston Technical College. 7 p.m.

North East Coast Institution of Engineers and Shipbuilders. "Investigation of Blistering and Mildew of Motor Cars in Course of Transport by Sea to Australia," by E. A. Shipley. Mining Institute, Newcastle upon Tyne. 6.15 p.m.

1st March

Institute of Metal Finishing (Midland Branch). "Stress and Fatigue in Chromium Plating Steel," by J. E. Stareck, E. J. Seyb and A. Tulumello. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 6.30 p.m.

Institution of Engineering Inspection (Coventry Branch). "Heat Treatment," with film, by D. Thomas. Room A5, Coventry Technical College. 7.30 p.m.

Sheffield Metallurgical Association. "Segregation in High Speed and Other Tool Steels," by E. Johnson. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

2nd March

Institute of Welding (East of Scotland Branch). "Low Hydrogen Electrodes," by Mr. Oldridge. Chamber of Commerce, Charlotte Square, Edinburgh. 7 p.m.

Institute of Welding (Manchester Branch). "Some Welding Problems in the Chemical Industry," by E. J. Heeley. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

3rd March

Institute of Metal Finishing (North-West Branch). "Anodising," by N. Pullen. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

Institute of Welding (North Eastern (Tyneside) Branch). "Site Welding," by W. C. Holliday. Mining Institute, Neville Hall, Newcastle upon Tyne. 7 p.m.

Institute of Welding (Portsmouth Branch). "The Productivity Aspect of Welding," by A. G. Thompson. College of Technology, Portsmouth. 7 p.m.

Institute of Welding (South Wales Branch). Film Show on Latest Developments in Various Branches of Welding. Grand Hotel, Port Talbot. 7.15 p.m.

Institute of Welding (Tees-Side Branch). "Fatigue in Welded Structures," by R. P. Newman. Cleveland Scientific and Technical Institution, Middlesbrough. 7.30 p.m.

4th March

Manchester Association of Engineers. "Electronic Aids to Production," by N. W. S. Ingles. The Engineers' Club, Albert Square, Manchester. 6.45 p.m.

West of Scotland Iron and Steel Institute. Joint meeting with the **Iron and Steel Engineers Group.** Engineering Aspects of Heavy Section Mills," by T. Walker. Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2. 6.45 p.m.

Society of Instrument Technology (Fawley Section). "Mass Spectrometers," by K. J. Knowles. Copthorne House, Fawley, Hants. 7 p.m.

7th March

Institute of Welding (Sheffield and District Branch). "The Place of Radioactive Isotopes in Non-Destructive Testing," by G. F. Gribbin and R. S. Forbes. Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield. 7.15 p.m.

Sheffield Society of Engineers and Metallurgists. "The Place of Shell Moulding in the Foundry," by Dr. B. H. C. Waters. Joint Meeting with the Sheffield Branch of The Institute of British Foundrymen. College of Technology, Pond Street, Sheffield. 7.15 p.m.

Society of Instrument Technology (South Yorkshire Section). "The International Temperature Scale and its Industrial Significance," by J. A. Hall. The Technical College, Huddersfield. 7 p.m.

8th March

Sheffield Metallurgical Association. "Open Hearth Furnaces: (vi) Checkers." B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

Society of Instrument Technology (Manchester Section). "Strain Gauge Application," by Dr. J. H. Lambie. College of Technology, Manchester. 7.30 p.m.

9th March

East Midlands Metallurgical Society. "Zinc Base Die Castings," by R. W. Bailey. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of Fuel. "Recent Coal Processing Research," by Dr. D. C. Rhys Jones. The Engineers' Club, Albert Square, Manchester. 2.15 p.m. Preceded by a members' luncheon at 1 p.m.

Liverpool Metallurgical Society. "Siliceous Refractories," by Dr. G. B. Rigby. Joint Meeting with the North Wales Metallurgical Society. The County Primary School, Plymouth Street, Shotton. 7 p.m.

Manchester Metallurgical Society. "Some Metallurgical Problems Imposed by Stratospheric Flight," by Major P. L. Teed. Lecture Room, Central Library, Manchester. 6.30 p.m.

10th March

Institute of Fuel. "Fuel Developments in Germany," by Dr. W. Gumz. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Institute of Welding (South London Branch). "The Plurial Welding Process," by M. Lebrun. 2, Savoy Hill, London, W.C.2. 6.30 p.m.

Institute of Welding (South Western Branch). "Titanium, Welding and Other Joining Methods," by D. C. Moore. Bristol Aeroplane Co., Ltd., Weston-super-Mare.

Aluminium in Britain is a Hundred Years Old

By E. G. West, B.Sc., Ph.D., F.I.M.
Technical Director, Aluminium Development Association.

It is just about a hundred years since the first piece of aluminium was made in Britain, and to mark the fact an Exhibition is to be held in London in June of this year. The last fifty years have seen a great expansion in production facilities and the development of an extensive range of alloys, both of which have contributed to the present day widespread use of the metal.

IT is only a few weeks short of a century from the date when the first piece of aluminium made in Britain was shown by Faraday to an audience at the Royal Institution. It had been made by Mr. Allan Dick and a Mr. Smith, using the chemical process developed in the previous year by Henri St. Claire Deville in France. The Royal Institution meeting took place on 30th March, 1855, and some months later the reduction of aluminium from cryolite by sodium was proposed by Dr. Percy; the reaction was successfully carried out a little later by Dick. Interest in the new method was such that by the middle of the year Professor Pepper at the Royal Polytechnic had obtained from the Emperor Napoleon III a small bar of aluminium made by Deville which was exhibited at the Polytechnic where it aroused great interest.

The subsequent commercial development of the metal, first by the sodium process and, towards the end of the century, by the electrolytic Hall-Heroult process, is well known, and it is only necessary to recall that it is now just about fifty years since the classicial researches into the heat treatment of aluminium alloys began. Wilm's first patent for an aluminium-copper alloy was taken out in 1903 and his patent for the duralumin-type alloys followed in 1906.

Increased Production Facilities

World output of the metal at the beginning of the present century was between 5,000 and 10,000 tons per annum, and since then the production of aluminium has been doubled roughly every ten years. There is little doubt that world production during 1954 amounted to about 3 million tons—a new record. Future production may not show quite such a spectacular increase but plans which have recently come to fruition and those which are now under active consideration or, in some cases, where construction is taking place, show that the producers are expecting to maintain a high rate of increase. The most spectacular development during the past year was, of course, the commencement of operations at Kitimat in British Columbia, where the immediate production will be but little short of 100,000 tons a year and the next phase of the scheme has already made progress. Ultimately, the Kitimat smelter will be the biggest single aluminium reduction scheme in the world.

In the U.S.A. a new plant at Arkadelphia with an annual capacity of 55,000 tons was brought into operation and, in addition, two very large expansions of alumina production were also started up, that at La Quinta having an annual output of 365,000 tons of alumina.

In Europe some 50,000 tons per annum of new smelting capacity were brought into being, the largest single contribution being the Sunndalsoera plant in Norway, with new capacity of 40,000 tons annually. Austria has expanded two of its plants by a total of more than 5,000 tons, whilst Sweden and Spain both brought 3 to 4,000 tons capacity into active use. It is, of course, speculative to estimate what changes may have been made in Eastern Europe but there seems little doubt that behind the Iron Curtain expansion of the aluminium industry is going forward.

More new plants were also taken from the drawing board into the stage of construction or near-construction. Thus, the new Australian plant at Bell Bay, Tasmania, and the Anaconda plant at Columbia Falls, both made progress towards the time when they would come into operation. Further away still from production are the plants projected for 40,000 tons per annum in the French Cameroons by the Alucam concern and the Oregon plant of the Harvey Company in U.S.A.

Perhaps the most striking feature about aluminium—certainly during the past fifty years—has been the stability of its price, and it is of interest to compare prices of aluminium and some of the other common metals twenty-five years ago and now. Briefly, the changes of average prices during the period 1929 to 1954 have shown that the cost per ton of aluminium to-day is very slightly less than the cost a quarter of a century ago, but for a few years (1943–46) it was some 30% lower than to-day. Whilst aluminium has not risen above the 1929 figure in that period, copper, zinc, lead and tin, are all double the 1929 figure to-day, and during the last few years have been very much higher still. There is no doubt that this price stability has greatly assisted the commercial utilisation of aluminium, and in the light of to-day's comparative costs and recent history it seems that this advantage may well continue; it should be exploited to the full by the aluminium industry and the users of the light alloys.

A Decade of Progress

It is now possible to look back virtually ten years since the second World War was drawing to its close and thoughts were turned to the possible utilisation of the then swollen capacity for producing and fabricating aluminium. The record is encouraging and if the same proportionate advance can be made in the next ten years the rate of increase of reduction capacity will have to be

maintained at the same level as has been the case during the past half century.

It will be recalled that one of the first new uses of aluminium in the post-war period was for the manufacture and erection of more than 50,000 pre-fabricated aluminium alloy bungalows, which were intended to have a ten-year life. This project not only helped to ease the housing problem but also introduced aluminium in a striking manner to general building, and thence to structural engineering. The growth of a pre-fabricated building industry in Britain has not been paralleled elsewhere in the world, but an even more spectacular application, namely, that of curtain walling to large buildings, has spread throughout the U.S.A. with amazing speed since the experimental 35-storey building of Alcoa was completed within the last two or three years. This trend towards modern high speed building is already arousing interest in Britain, and with the experience already gained over here on structural applications and pre-fabricated buildings, coupled with research in hand on several aspects, rapid progress should be made in the introduction of aluminium to this field.

Ten years ago the aluminium industry was faced with the task of re-establishing itself in the road vehicle industry, from which it had been virtually prohibited by the aircraft demands of war-time. Not only has the use of aluminium by the automobile engineer been brought back to the pre-war level but it has been greatly extended and some major engineering advances made, such as the new light alloy chassis-less double-decker bus sponsored by London Transport. The application of aluminium to railway vehicles was also on a very small and tentative scale ten years ago, whereas now there is running experience of a very satisfactory nature of no less than 90 aluminium coaches on the London Underground system, and of many fittings on British Railways main line trains; valuable export business has already been undertaken with aluminium railway rolling stock. There is, however, still a long way to go in this field before the maximum savings of power and maintenance can be achieved in Britain.

Research into the large-scale use of aluminium in ocean-going vessels was only just beginning in 1945, but many technical problems have been satisfactorily tackled with the result that aluminium is being widely accepted for ships' superstructures, even to the extent of using 2,000 tons on the S.S. *United States*. Investigations into big rivets and into the application of the new inert gas welding processes have shown that large structural elements can now be fabricated by either method. Indeed, very recently the aluminium alloy superstructure of the 12,700 tons steamship *Sunrip* was completed—the largest all-welded light alloy superstructure to date. This vessel was built in Quebec and has been chartered to Saguenay Terminals Ltd., the subsidiary of Alcan responsible for carrying bauxite or, in this case, alumina, from Jamaica to the smelter.

Another spectacular advance during the past ten years has been the growth of the packaging applications of aluminium. Methods of producing and using cans for foodstuffs and other products have been established on a commercial basis and the amount of foil now used for packaging purposes has reached a new high level. It seems likely that during 1954 well over 16,000 tons of foil were rolled in Great Britain, and there seems to be a large untapped market for foil still, particularly when compared with its production and utilisation in the United States.

The large-scale entry of aluminium into the electrical engineering industry is dealt with elsewhere in this issue, and space in this brief review does not permit mention of the many other uses in general engineering and in new applications such as toys, costume jewellery, radio and television, new forms of domestic equipment, items for sports and games, office equipment and furniture.

London Centenary Exhibition

To celebrate its first Centenary, and to give engineers and the public a chance to see what aluminium has done, and even more important, what it can do in the future, the Aluminium Development Association is arranging an Exhibition to be held in London during June, 1955. The record of a century of British progress with aluminium will undoubtedly point the way to that future which will see even more spectacular advances in considerably less time than a hundred years.

Plant Engineering Courses

A SCHEME of examinations in Plant Engineering has been drawn up by the City and Guilds of London Institute's Advisory Committee. The scheme is intended to meet the needs of those engaged in the selection, installation, maintenance or control of fixed or mobile plant throughout industry. Examination courses, approved by the Council of Incorporated Plant Engineers as meeting the examination requirements for their Associate Membership, are designed to follow the successful completion of an Ordinary National Certificate course in mechanical or electrical engineering.

A Certificate in Plant Engineering will be awarded to successful candidates, and the possession of this Certificate will give exemption from the technical part of the entrance examination of Incorporated Plant Engineers. In addition, the City and Guilds of London Institute will award a Full Technological Certificate (countersigned by the President of Incorporated Plant Engineers) to candidates who have gained the Plant Engineering Certificates and have an Ordinary National Certificate or higher qualification.

Full details of the scheme of examinations in Plant Engineering may be obtained from the Department of Technology of the City and Guilds of London Institute, 31, Brechin Place, South Kensington, London, S.W.7, the General Secretary of Incorporated Plant Engineers, Solihull, Birmingham, or through technical colleges.

French Order for Brightside

THE Brightside Foundry and Engineering Co., Ltd., Sheffield, has received a contract from the Société Métallurgique d'Imphy, France, for a bar and continuous rod mill for the production of precision alloy steel bars and rods in straight lengths and coils. Provision will be made for the plant to roll strip also. The value of the mechanical equipment is considerably over £500,000 sterling, and the contract provides that some parts are to be made in France to " Brightside " designs.

Société Métallurgique d'Imphy, formerly known as S.A. Commentry-Fourchambault et Décazeville, are well-known for their high quality alloy steels and operate blast furnaces, open hearth furnaces and electric furnaces, together with rolling mills, forges and foundries.

Super Purity Aluminium

Production, Properties and Applications

By E. E. Spillett, B.Sc.

Development Manager, Sales Division, The British Aluminium Co., Ltd.

The 99·99% purity aluminium which is produced by a double electrolytic process has characteristics which make it especially suitable for use for certain purposes. As a result the demand for it is increasing, and in this article the author discusses its properties and details typical applications.

PRODUCTION

SUPER Purity aluminium, as the name implies, is metal of a much higher aluminium content than that commonly termed 'normal' or 'commercial,' where the impurities may total up to 1%. The major impurities in Super Purity are silicon, iron and copper, which in total amount to less than 0·01%, giving an overall purity of over 99·99%.

The purity of aluminium produced by the electrolytic reduction of alumina, a process developed from the pioneer work nearly 70 years ago by Hall in America and, independently, by Heroult in France, is usually of the order of 99% to 99·8%. To produce Super Purity metal a second electrolytic process is necessary. This can be carried out in a cell having three liquid layers of different densities, and such a cell is pictured diagrammatically in Fig. 1. The bottom layer consists of relatively impure aluminium alloyed with copper to increase the density to about 3 g./cc. in the molten condition, and forms the anode. Immediately above this is a layer of fused electrolyte, whilst the top layer, forming the cathode, consists of pure metal with a density of 2·3 g./cc. in the liquid state. The intermediate layer of molten electrolyte with a density of 2·7 g./cc. is a suitable mixture of fluorides, or fluorides and chlorides, usually of sodium, barium and aluminium—barium giving the required density. The liquidus of this layer is in the region of 720° C., the furnace operating at a temperature of 740° C.

The side walls of the furnace are lined with magnesite bricks, surrounded by refractory or insulating bricks, with a steel outer casing. The current is introduced through iron bars and carbon blocks in the bottom of the cell, and taken out through graphite blocks dipping into the layer of pure aluminium at the top. The depths of the layers may be 8–10 in. at the bottom, 6–10 in. for the electrolyte, and 3–4 in. for the top layer of pure aluminium. Such a cell may operate at 6–8 volts and 25,000 amps., with nearly 100% current efficiency.

As the aluminium content of the bottom layer is reduced, low purity aluminium is introduced, either through a graphite tube inserted into the cell or by pouring it into a forewell connected to the anode layer. The alloy constituents which gradually accumulate in the anode layer, can crystallise out into such a forewell, which is somewhat cooler than the rest of the bath, and can be removed periodically by dredging. Super Purity metal is removed from the top layer by ladles, and great care must be exercised in performing all these operations in order to avoid disturbing the three-layer system.

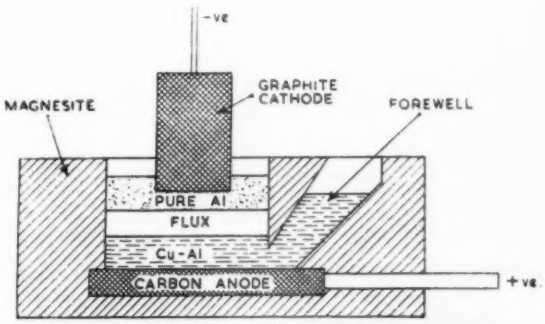


Fig. 1.—Diagram of three-layer refining cell.

Super Purity aluminium can be made into the same semi-fabricated wrought forms as commercial purity aluminium, i.e., sheet and strip, circles, tubes, extrusions, and wire, with somewhat similar production procedures. For rolled products a cast block (chill cast in a permanent mould or continuously cast) or an extruded bloom is hot rolled to a convenient thickness, followed by cold rolling, intermediate annealing being carried out when necessary. Similarly, for wire a wire-bar is first hot rolled, followed by cold drawing, whilst sections are extruded from preheated billets, although a somewhat lower extrusion temperature can be employed (see later).

With Super Purity, however, extra special care must be taken during these fabrication processes to avoid contamination, and so preserve the excellent corrosion resistance which is an inherent characteristic of the material. Similarly, owing to its extreme softness, great care must be taken in handling the metal to avoid damage.

Metals of high purity are susceptible to grain growth and Super Purity aluminium is no exception, and it is necessary to employ carefully controlled annealing conditions. Unlike commercial purity material, Super Purity should not be heated rapidly during annealing; a finer grain size is obtained when the metal is heated slowly, and a temperature of 350° C. should not be exceeded.

PROPERTIES

Super Purity Metal

The outstanding characteristics of Super Purity aluminium are its excellent corrosion resistance; its relative softness with high ductility, easy workability and low rate of work hardening; its high thermal and

TABLE I.—TYPICAL MECHANICAL PROPERTIES OF SHEET AND STRIP.

Property	Super Purity (99·99%)		Commercial Purity (99%)	
	Soft	Hard	Soft	Hard
Tensile Strength (tons/sq. in.) ..	3·5	7·0	5·8	10·3
Elongation (% on 2 in.) (20 s.w.g.). .	50	7	34	4
Brinell Hardness. (H/1/5)	15	29	22	42

TABLE II.—CONDUCTIVITY AND REFLECTIVITY.

Property	Super Purity (99·99%)	Commercial Purity (99%)
Relative Heat Conductivity (Silver = 100%) ..	57·1	54·1
Relative Electrical Conductivity (Copper = 100%)	64	60
Light Reflectivity (Brytal treated)		
Total (%)	84·1	65
Specular (Parts in 100)	99·4	80
Diffuse (Parts in 100)	0·6	20

electrical conductivity; its excellent anodising properties; and its high reflectivity, both total and specular, when treated by the Brytal* electrolytic brightening process. Tables I and II show typical values of some of its outstanding properties in comparison with those of metal of commercial purity (99%). On extrusions somewhat similar properties are obtained to those quoted in Table I for soft temper sheet and strip.

In general the higher the overall purity of aluminium, the greater its resistance to corrosive attack. Laboratory tests clearly indicate the superiority of Super Purity, particularly in the acid range, as exemplified in Tables III–V.

Alloys Based on Super Purity Metal

For applications where the relative softness of Super Purity aluminium may be a handicap, the metal can be alloyed with appropriate elements to obtain increased strength without materially affecting other desirable characteristics. Magnesium in small quantities will increase the hardness and strength with comparatively little effect on the reflectivity, as is shown in Tables VI and VII. Although the diffuse component has increased slightly with the addition of magnesium, the total reflectivity is still high.

When greater hardness in extruded products is required BA.SP.16, a magnesium-silicide type alloy with Super Purity base, can be used. BA.SP.16 contains 0·7% magnesium, 0·3% silicon and 0·25% copper, and in the fully heat-treated condition, i.e., 'WP,' has a tensile strength of 17 tons/sq. in. with a Brinell hardness of 90. This alloy has a good machining characteristics, and after treatment by the Brytal process has a lustrous and highly reflecting surface, indistinguishable visually from that obtained on Super Purity. Continental trade literature quotes a total reflectivity of 83% to 85% for an alloy of this type and also for Super Purity base alloys containing up to 2% magnesium. Optimum results on the magnesium-silicide types of alloy, however, are only obtained when they are correctly heat-treated.

For chemical plant and similar applications where the highest possible corrosion resistance, coupled with reasonable strength, is demanded, a Super Purity base alloy containing manganese (patent applied for) is under development. This alloy, whilst possessing similar mechanical properties to those of NS3 (B.S.1470), i.e., twice as strong as unalloyed Super Purity, has a resistance to corrosive attack of the same order as Super Purity and much higher than NS3. For example,[4] in hot acidified salt solution (1%) the relative corrosion rates are as follows :—

	g./sq. m./day
Super Purity	8
Super Purity, plus manganese	9
BA.60 (NS3)	27

TABLE III.—CORROSION IN SULPHURIC ACID.[1]

Sulphuric Acid%	Loss of Weight on Samples	
	99·5% Purity g./sq. m./day	Super Purity g./sq. m./day
0·5	0·7	0·3
1	1·2	0·4
2·5	1·5	0·5
5	1·8	0·6
10	2·4	0·8
20	2·9	1
50	10	2·7
93·5	35	27·5

TABLE IV.—CORROSION IN HYDROCHLORIC ACID.[2]

Purity	Loss in Weight of Specimens (g./sq. dm.)	
	5·7% HCl (by weight)	38% HCl (by weight)
99·5% Super Purity	10 in 3 hours 0·044 in 52 hours	10 in ½ hour 0·06 in 16 hours

TABLE V.—CORROSION IN SALT SOLUTION.[3,4]

Purity	Pitting with Intermittent Immersion in 3% NaCl (*p*H 3)	Loss of Weight in 10% HCl at 25° C.
99·8% Super Purity	10 mils 7 mils	220 g./sq. m./day 5 g./sq. m./day

* Registered Trade Mark

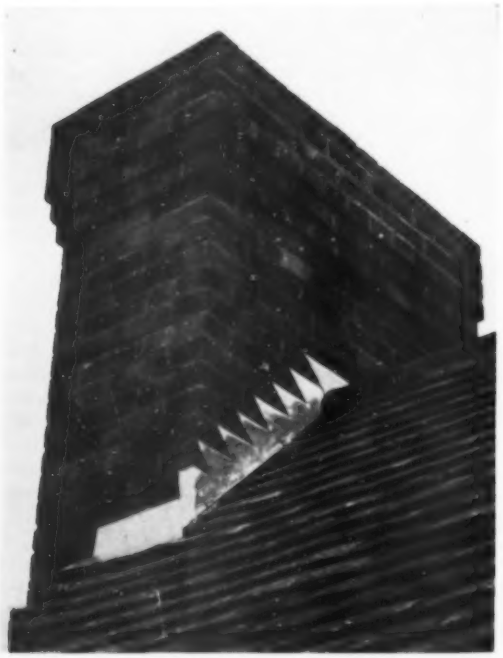


Fig. 2.—Chimney flashings in 20 s.w.g. Super Purity aluminium.

APPLICATIONS

It was not until the years immediately preceeding the Second World War that Super Purity aluminium became available in sufficient amounts to justify commercial application, and during the war years the limited quantity available was mainly restricted to reflectors for Service requirements. It was covered by specification

under the designation A1 in the BS/STA.7 Services Schedule of Non-Ferrous Metals and Alloys, Group 6.

Increased production within the last decade has enabled a variety of other applications to be developed and established, and Super Purity in sheet, strip and wire forms will be included in the B.S. General Engineering series of specifications now undergoing revision. No figures are yet published regarding World production of Super Purity metal, but, a study of isolated references in literature indicates that between 7,000 and 10,000 tons are already being produced annually.

Although naturally more expensive than the lower purities of aluminium, Super Purity is by volume competitive with many of the other non-ferrous metals and alloys. The development of uses of Super Purity aluminium has logically followed an exploitation of its inherent characteristics, and some applications, both established and potential, are discussed in this section under appropriate headings.

Flashings and Weatherings (including Roofing)

The high ductility of annealed Super Purity aluminium renders it an excellent material for flashings and weatherings; while not possessing the full workability of lead, its ease in forming is second only to that of lead. Its durability, comparatively low price, and ready availability also make it an attractive proposition for many types of these building applications. Its use has steadily increased over recent years and today Super Purity is accepted throughout the building industry as a high quality flashing material, enjoying the confidence of both the architect and the plumber.

In housing work, it is used for chimney flashings, vent-pipe flashings, cavity flashings, bay tops, dormer tops and cheeks, and damp proof courses. On the Breightmet Housing Estate being built by the Bolton Corporation, Super Purity aluminium is being used for flashing work on some 3,000 houses at a cost of only two-thirds of that which would have been expected had more traditional metals been used.

Contemporary architectural design, with its low pitched roofing, is turning to the thin sheet metals as a means of weathering such roofs. Super Purity aluminium, which can be expected to take on a pleasant dull silver-grey finish after exposure to the atmosphere, has been found

TABLE VI.—EFFECT OF MAGNESIUM ADDITION ON TYPICAL MECHANICAL PROPERTIES.

Property	Temper	Super Purity	BA.SP.11 (Super Purity plus ¼% Mg.)	BA.SP.12 (Super Purity plus 1¼% Mg.)
Tensile Strength (tons/sq. in.)	Soft	3·5	6·0	8·0
	½H	5·5	8·0	11·0
	H	7·0	11·0	14·0
Brineil Hardness (H/1/5) ..	Soft	15	22	31
	½H	24	34	48
	H	29	47	60

TABLE VII.—LIGHT REFLECTIVITY AFTER BRYTAL TREATMENT.

Material	Total (%)	Specular (Parts in 100)	Diffuse (Parts in 100)
Super Purity	84·1	99·4	0·6
BA.SP.12 (Super Purity, plus 1¼% Mg.)	83·5	97·1	2·9

TABLE VIII.—PROPERTIES OF EXTRUDED MATERIAL.

	Super Purity (99·99%)	Commercial Purity (99%)
Extrusion Temperature	350° C.	450° C.
0·1% Proof Stress (tons/sq. in.)	2·9	3·2
Tensile Strength (tons/sq. in.)	4·6	7·0
Elongation (% on 2 in.)	46	39

Courtesy of London County Council Architect's Department, and Builders' Iron and Zincwork, Ltd.

Fig. 3.—Flat roofing in 20 s.w.g. Super Purity—school in South West London.

to fit in well with this modern style of construction, and has been specified by architects for such buildings as schools and churches. For example, the Berkshire County Architect recently used this material to cover roof surfaces totalling 15,000 sq. ft. on a new school. In the London area, noteworthy roofs completed during the past twelve months or so, include a church hall at White City and a new church at Oxhey. In this field also, Super Purity is less expensive than its main competitors, and it would be fair to say that a roof can be laid in this material for approximately 75% of the cost of a comparable copper roof, and less than 50% that of a lead roof.

Some instances of these applications are shown in Figs. 2 and 3.

Cable Sheathing

This is a potentially large application, and is another one where the high ductility and good durability of Super Purity should be of value. Aluminium is already being used instead of lead, and although aluminium-sheathed cable has many advantages, it is more rigid and consequently less easily manipulated. Of the available purities of aluminium, Super Purity has the lowest strength and highest ductility, both important properties in the production of aluminium-sheathed cables by direct extrusion.

Super Purity can be extruded more easily, and laboratory tests[4] have shown that ½ in. diameter solid bars can be extruded at about two-thirds the pressure required to extrude similar bars in commercial purity material. Similarly, for any given pressure, the Super Purity can be extruded at a temperature of some 100° C. lower; an important point when there is a risk of burning the insulation. Furthermore, the lower rate of work hardening of Super Purity can give a more ductile product even

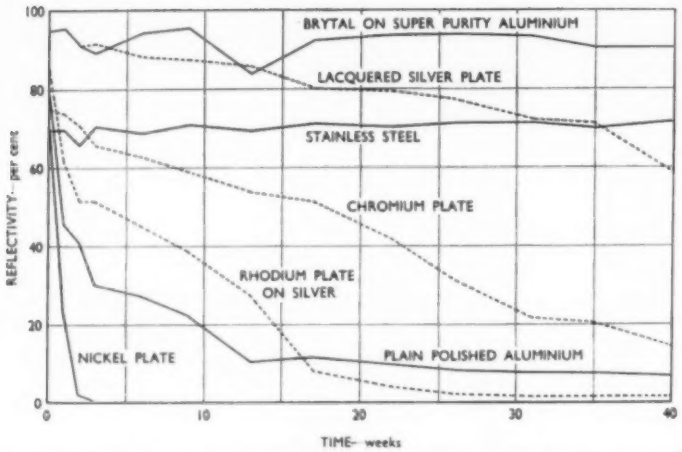


Fig. 4.—Variation in reflectivity with time, of samples freely exposed to atmosphere (relative to silvered glass as 100).

when extruded at a lower temperature, as will be seen from Table VIII. It would appear, therefore, that it should be possible to extrude a cable sheath in Super Purity metal at a lower temperature and pressure than in commercial purity and yet still obtain a more ductile sheath.

Electrolytic Condensers

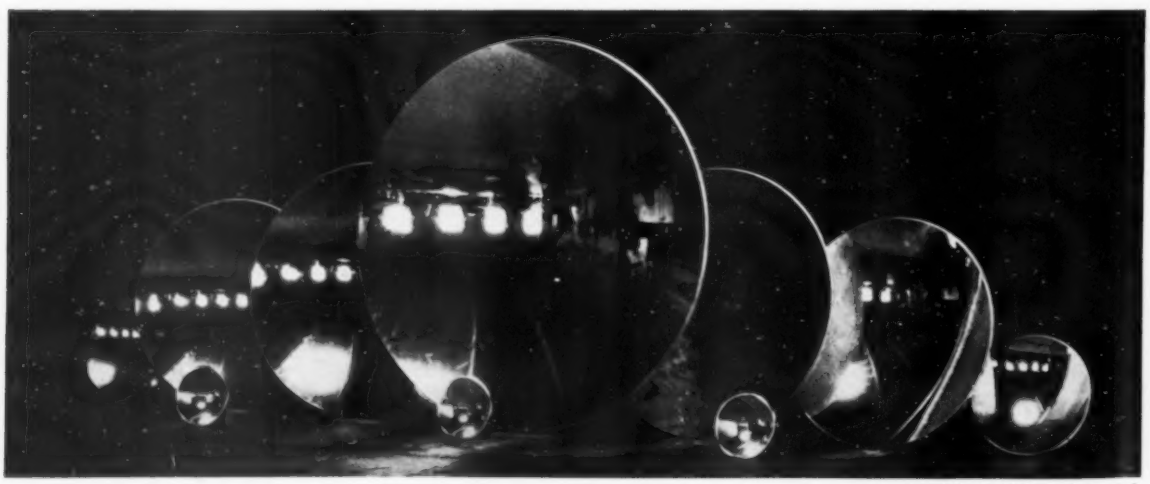
Another electrical application is the use of Super Purity aluminium foil in the construction of electrolytic condensers, which are important components of electrical and radio equipment. Its superior properties give advantage to both manufacturer and user: to the manufacturer it has better anodic film forming properties and leads to higher recoveries in processing.

The relatively high electrical capacity of the electrolytic condenser permits greater compactness, an important consideration in the design of electronic and ancillary equipmnent with its complex arrangements of components and circuits, but when made from 99·8% aluminium they have the disadvantage of relatively poor shelf-life and a high leakage current compared with the more bulky mica or paper dielectric condensers. Electrolytic condensers made from Super Purity aluminium, however, have better shelf-life and lower leakage current than is the case with 99·8% purity metal, thus enabling fuller advantage to be taken of the compactness of this type of condenser. Tests have shown that the average shelf-life is more than doubled when Super Purity aluminium foil is used, and such condensers have a quicker recovery, i.e., film reforming rate after idle periods. For example, although there is no difference between the puritics when the idle period is 24 hours or less, the Super Purity will recover in a matter of seconds after a week of inactivity, as compared with 3 to 4 minutes for 99·8% purity, and Super Purity condensers may remain idle for 5 or 6 months without appreciable deterioration in the recovery rate. The leakage current of such condensers is only about one-third of that customary with 99·8% purity material, and the consequent lower operating temperature leads to greater reliability and longer life.

All these advantages go far to explain the great increase in the use of Super Purity aluminium for this purpose in the last few years, a period when increasing quantities of electronic equipment have been manufactured for the Services and industry, equipment in which the standard of reliability demanded from components is often even higher than in radio and television apparatus.

Reflectors

The excellent reflectivity of Super Purity aluminium when Brytal treated has already been mentioned and Table IX shows how it compares with other reflecting surfaces. These values were obtained by the National Physical Laboratory on flat specimens 6 × 3 in. using light from a gas-filled lamp. The light was incident at approximately 45°, and the total light reflected is



Courtesy of Clarke, Chapman & Co., Ltd.

Fig. 5.—Super Purity aluminium reflectors in searchlights 5, 10, 20, 24 and 36 in. diameters, all electrolytically brightened by the Brytal process.

TABLE IX.—COMPARATIVE REFLECTIVITY.

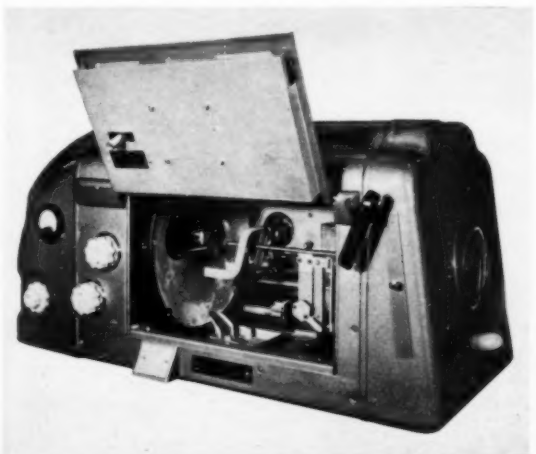
Specimen	Total Reflectivity %	Specular Parts in 100	Diffuse Parts in 100
Brytal on Super Purity Aluminium	84·1	99·4	0·6
Stainless Steel	59·5	97·0	3·0
Chromium Plate	63·0	99·7	0·3
Rhodium on Nickel Plate	69·1	99·55	0·45
Lacquered Silver Plate..	89·8	96·5	3·5

expressed as a percentage of the incident light and the proportion of specular and diffuse reflection in the total is expressed as parts in 100.

The high durability of Brytal-treated Super Purity is shown in Fig. 4, which depicts the results of exposure tests in an industrial atmosphere on different reflecting surfaces. Brytal-treated reflectors are shown to have the same order of durability as stainless steel, whilst being at least 20% more efficient as reflectors. The suitability of Super Purity aluminium for searchlights and aircraft landing lights was firmly established during the war and its use has now been extended to mines, ships' holds, airport runways, etc. Some examples are shown in Figs. 5 and 6.

Decorative Applications

The Brytal process is carried out in two stages—the first designed to brighten the surface electrolytically,



Courtesy of The British Thomson-Houston Co., Ltd. and Clarke, Chapman & Co., Ltd.

Fig. 6.—Cinema projector lantern with Brytal Super Purity reflector.

and the second to form a protective film without materially affecting the brightness obtained during the first operation. It is essential, however, that the metal should be carefully mechanically polished before treatment in order to obtain optimum results.

For decorative applications where a bright, lustrous, and non-tarnishing finish is required, but not to such an exacting standard as demanded for reflectors, bright dips are becoming increasingly popular. They have the advantage of being speedy in operation, and mechanical polishing prior to treatment can be reduced, or even omitted. There are numerous bright dips, mostly covered by patents. Some considerably improve the brightness of commercial purity aluminium but as the impurities in the base metal increase the anodic film subsequently formed to protect the bright surface is less

Courtesy of Harman Bros., Ltd., Roy Tallent, Ltd., H. B. Sale, Ltd., J. R. Gaunt & Son, Ltd. and Biro-Swan, Ltd.

Fig. 7.—Group of miscellaneous articles incorporating Super Purity and Super Purity base alloys.

transparent, so that for optimum results Super Purity metal is still required.

Applications of brightened and anodised (and sometimes dyed) Super Purity are rapidly becoming too numerous to detail. Some of the more outstanding include: watch bezels, costume jewellery, cigarette cases, military badges and buttons, decorative trim for cars and coaches, decorative trim for refrigerators and other household equipment and appliances, lipstick containers, clock cases, propelling pencils, fountain pen caps, vases, bowls, and cocktail sets. Some of these are depicted in photographs in Figs. 7–10.

Super Purity Cladding

It has often been considered that it might be worth while to use an alloy sheet clad with Super Purity for decorative applications in order to obtain the requisite strength and at the same time a highly lustrous surface; but as the relatively soft and thin layer of cladding may be removed in places during polishing, particularly if

Courtesy of Acorn Anodising Co., Ltd.

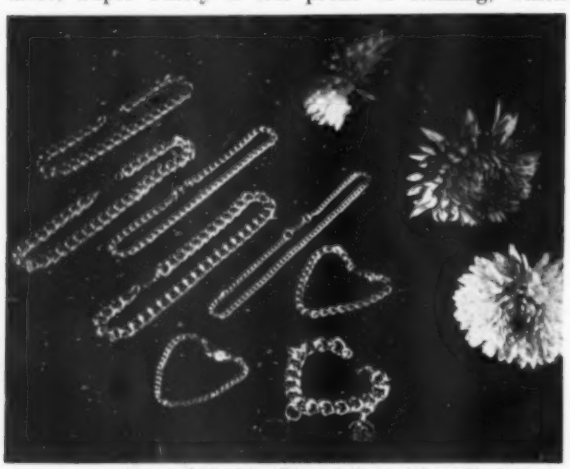
Fig. 8.—Cocktail set and tray made from Super Purity aluminium.

Courtesy of Duple Motor Bodies, Ltd.

Fig. 9.—Motor coach incorporating BA. SP.12 alloy trim.

heavy, it is preferable to use a Super Purity base alloy where higher strength is required. However, an interesting application of cladding with Super Purity metal to enhance resistance to corrosive attack is now under development.

Alloys of good intrinsic corrosion resistance may be liable, in certain conditions, to pitting attack, and cladding with Super Purity may be beneficial, providing the cladding is anodic to the core metal. If the cladding is penetrated, either mechanically or by corrosion, it gives sacrificial cathodic protection to the core, thereby considerably reducing the possibility of perforation by pitting. An instance of this is in kettle bodies, where traces of copper in the supply water can cause fairly rapid failure of unclad material. Extensive laboratory tests,[4] followed by service trials, of Super Purity cladding on 1¼% manganese alloy (patent applied for) suggest this may be the answer to the pitting problem in aluminium kettles. This composite material would, in addition to minimising pitting, combine the excellent durability of the Super Purity material with the strength and general resistance to mechanical damage of the alloy; furthermore, Super Purity is less prone to staining, which



Courtesy of Aluminium Wire & Cable Co., Ltd. and Riveria Pearls.

Fig. 10.—Anodised and dyed jewellery from Super Purity aluminium wire.

Fig. 11.—Laboratory test specimens showing effect of cladding BA.60 with Super Purity aluminium.

sometimes occurs in certain natural waters. Fig. 11 reproduces photographs of laboratory test samples which were partially immersed for four months in 3% sodium chloride to which acid had been added to lower the *p*H to 3, indicating the advantage that can be obtained.

The use of clad metal would not be practicable in saucepans and other utensils which may be frequently cleaned with steel-wool or abrasives, as the relatively soft Super Purity coating might soon be removed; its use is likely to be confined to kettles, percolators, etc.

Conclusion

This survey shows that Super Purity aluminium, the product of a double electrolytic process, is no longer a laboratory curio of somewhat higher purity than that obtained from the basic Hall-Heroult process. Its inherent characteristics, associated with its high purity, enable it to enter a wide range of applications, and already it is becoming established as a material in its own right. Although present production is small compared with that of commercial purity aluminium, there are no technical difficulties involved in further expansion of production to meet increasing demand.

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4 Unpublished work carried out in the Research Laboratories of The British Aluminium Co., Ltd.

Rutherford Memorial Lecture

THE Council of the Royal Society has appointed Professor M. L. E. Oliphant, F.R.S., of the Australian National University, as the Rutherford Memorial Lecturer for 1955. Professor Oliphant will deliver lectures in India and Pakistan.

Aluminium and its Alloys in 1954

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., A.I.M.

The Aluminium Development Association.

Attention is drawn to work published in this country and the U.S.A. reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution and properties. Reference is also made to interesting applications of these materials.

ALTHOUGH to English people the most famous anniversary celebrated last year was that of the birth of an eminent Knight of the Garter, 1954 was notable also as the hundredth year since Henri St. Claire Deville laid the foundation of the French aluminium industry by his discovery of the first commercially applicable method for the production of aluminium. This event was very adequately remembered by a Congress and Exhibition in Paris, which attracted considerable attention throughout the world, and was voted a great success by those who saw and wrote about it.[1,2,3] The general slogan of the exhibition, which set out to appeal to the general public, was "Aluminium, the metal that has given wings to progress." Both manufacture and applications were illustrated, and papers were presented by authorities from various countries throughout the world.

Perhaps influenced by this atmosphere of anniversary, West[4] has looked at the aluminium industry in this country and summed up the materials it manufactures, its production capacity, and the development of new applications. He shows clearly how, from a small industry providing rather special materials for limited application, has grown a well-equipped group of companies producing standard alloys in standard forms for large and diverse markets, to which additions are continually being made.

Production

On August 3rd, 1954, the Duke of Edinburgh lifted from the smelter production line the first ingot of aluminium to be poured at Kitimat, and so inaugurated the great hydro-electric scheme and extraction plant which will eventually double Canada's capacity for the manufacture of primary aluminium. The ceremony has been described[5] with illustrations which give some idea of the magnitude of the project, and emphasise the shortness of the time—three and a half years—in which this stage has been reached. It is particularly encouraging to know that the world needs such enormous increases in the supply of aluminium metal, and comforting to note, in an article[6] on aluminium in the Commonwealth, that at present well over a quarter of the world's supply of bauxite comes from Empire sources, and that this proportion will increase as reserves in such countries as the Gold Coast, Australia and India are developed. This account provides a useful brief summary of present Commonwealth extraction facilities, and some consideration of likely future expansion, including, of course, the Volta River scheme.

Although a great deal of effort is devoted to research into the various chemical engineering and metallurgical processes involved in changing bauxite into aluminium, little account of it is published in the English language. Johnson's[7] paper on the costs of transportation of bauxite is, therefore, very useful, not only for the statistics associated with its main subject, but for its summary of the factors affecting investment and operating costs involved in virgin metal extraction. The high contribution to total costs of sea and land transport of either bauxite or alumina leads the author to suggest that the U.S.A. might have to turn to domestic clays and anorthosites at some future date, since the cost of treating such ores might eventually be less than that of importing foreign bauxites. This will surely lend attraction to the Volta River Scheme, where bauxite and potential water power lie together ready for exploitation.

"Bath sampling" has been the introduction of not a few metallurgists to the profession, and the necessity for having an analysis of the melt of metal as soon as possible, in order to permit adjustment of composition, has always conflicted with the chemist's requirements of time sufficient to ensure accuracy. The tremendous development of the secondary aluminium alloy industry has been largely due to the increasing realisation of the metal users that the refiners could be counted on to produce ingots to reliable specifications, and of accurately determined composition. This has involved a great volume of chemical analysis, helped by spectrographic determinations, and the latest tool, offering high accuracy and great speed, is the direct reading spectograph; a British installation[8] has been described during the year. Colwell and Tichy,[9] using similar equipment, have shown how a heat of scrap is melted, and its composition determined and adjusted by stages, to arrive at a casting alloy of specified composition. The authors consider costs, including both overheads and salaries, and feel that they are justified by the results obtained.

Melting and Casting

Reminders that we live in the age of the atom are not confined to international conferences and children's comics; the by-products of Harwell and similar institutions are used by the metallurgist as by other workers in pure and applied science. Autoradiography, involving activation of an alloying element in aluminium by exposure to neutrons, followed by allowing a period of decay and then taking contact prints, has been used by Putnam[10] and by Michael and Bever[11] to study the solidification of aluminium. (It is, of course, most

convenient that aluminium has a half-life for decay of only 2–3 minutes, while a more conservative metal such as copper takes over twelve hours for the same process). The former author actually used very small proportions of gold to illustrate the solidification boundary in semi-continuously cast billets of pure aluminium, and his paper includes most convincing pictures. The American investigators' work concerns aluminium-copper alloys, and they combine their autoradiography (using the alloying copper) with thermal analysis and metallographic examination to reach conclusions about the orientation and growth of dendrites. They also show that at all rates of cooling from 0·01° to 50° C. per second, non-equilibrium eutectic is present, and that it increases in quantity with rate of solidification, the theoretical maximum being approached more rapidly the higher the copper content over the range investigated, namely 2–5%.

Turning from billet to casting production, the book edited by Murphy[12] on non-ferrous foundry metallurgy contains a section devoted to aluminium alloys, and, of course, much of the general matter is relevant. The list of names of chapter authors is impressive, and the volume should be of value to both the foundry metallurgist and the student, although the latter may boggle a little at its price. Scheuer[13] and his co-workers have shown convincingly, and in truly scientific manner, how a lack of dissolved gas can be just as much a bane of the foundryman as a surfeit, particularly when making gravity die castings of geometry such that local soldification and shrinkage occur, encouraging hot-tearing. Bubbling of hydrogen gas into a melt is used to control accurately the gas content of the metal, and a delightful series of ingot slices with diminishing gas contents is illustrated; the frivolous reader is reminded of the cake stall at agricultural shows.

Although popular in America and on the Continent, the aluminium-zinc-magnesium naturally-age-hardening casting alloys have not been much used in this country, and it is interesting to read that a British foundry[14] has taken out a licence to make one of these alloys which is the subject of a U.S. patent. Despite casting difficulties, one feels that the strength and ductility (obtained without heat treatment), machinability and high corrosion resistance should encourage further attention to this class of alloy.

Working

At the Supplier's Works

Much progress has been made technically, and in industrial commonsense, since the days when Huntsman went to such great lengths to prevent possible competitors from obtaining the secret of manufacture of crucible steel, and the past year has seen the publication of several articles, well illustrated, describing works engaged in the production of semi-fabricated forms in aluminium and its alloys. Rowe[15] has discussed the plant, equipment and works practice at the British Aluminium Co.'s Falkirk factory, and in a very comprehensive article, full of detail, covers the production of sheet from ingot to despatch, with illustrations including three colour plates. It is good to read that the plant includes a line for the continuous anodizing of strip up to 24 in. wide, which presumably could be used for container sheet should economic circumstances merit expansion of production of aluminium food cans. Another works devoted to sheet and strip rolling is that of T.I. Aluminium, Ltd., at Resolven, and this has also been described[16]; aluminium is extensively used in the buildings that house the modern equipment.

One important product of both the above companies is foil stock, the raw material for the manufacturers of aluminium foil. French practice in rolling foil is exemplified by the techniques[17] employed by the Société des Trifileries et Laminoirs du Havre, which also extend to foil "conversion," including laminating to other materials, lacquering and multi-colour printing.

Post-war investment in new equipment for working aluminium and its alloys has been extensive, and the semi-continuous hot-rolling mill of the Aluminium Wire & Cable Co., Ltd., is one of the most modern in the world. A brief account [18] has been given of how this company converts wire bars into rod, and thence into wire of sizes down to 39 s.w.g., some of which, in electrical-purity aluminium, is subsequently stranded into conductor. Modern equipment does not eliminate the necessity for industrial skills, and this applies particularly to high-grade aluminium alloy forgings, the majority of which are of high-strength alloy for severely stressed applications in aircraft construction. Morgan [19] and Fletcher[20] have both described the advantages of forgings and considered future developments, particularly as regards the large sizes envisaged in America when the enormous presses are completed there. Fletcher notes that forgings must offer high properties, since otherwise they are open to competition from the strong and ductile aluminium-magnesium and aluminium-copper heat-treated casting alloys.

Extrusion is another process vital to the aluminium industry and again equipment has been described. The T.I. Aluminium plant at Redditch forms the subject of a paper by Lloyd,[21] which also includes a consideration of the fields of application of the various grades of pure metal and of standard alloys. Hollow sections and tubes are produced both from pierced billets and by the port-hole die method, and, where necessary, finished by cold drawing. The drawing capacity of the industry has recently been extended by the installation by James Booth & Co., Ltd., of a single-chain drawbench[22] of 150 tons pulling power, capable of producing 30 ft. lengths of tube up to 17 in. in diameter by mandrel or plug drawing. Across the Atlantic and at the other end of the scale, a Los Angeles company is using the Hooker process of impact extrusion to make very-thin-walled slim aluminium tubes [23] to very close tolerances, in lengths up to 36 in.

A most successful post-war application of aluminium has been the sheathing of power cables, by the process of threading the conductors through a tube which is then sunk down to give a close fit. A protracted study of the problems involved in direct extrusion of sheath on to cable, as is done with lead, has been fruitful, and the Prescot works of British Insulated Callender's Cables, Ltd., has recently acquired a specially designed press for this purpose. A description[24] of this equipment also reveals that, while further development work is still required, sheathed cables have already been produced with satisfactory properties.

The symposia held from time to time by the Institute of Metals on various subjects are extremely popular, and the papers presented and contributions to the discussion are important sources of practical technical information. That arranged for 1954 was devoted to the control of quality in working operations, and two

papers are of particular interest in the aluminium field. King and Turner[25] deal with hot and cold-rolled products, and show how attention must be devoted to many properties not covered by specification, and which are affected by the requirements of the user. The paper is a liberal education in the problems of the works metallurgist; many variables are acting at the same time, and all must be studied and their effects understood before full control of properties can be exercised. This also applies, of course, to the production of extrusions, and Smith and Swindells[26] have performed a similar task in this field. These authors are particularly expert in clear exposition, and they point out that the process of extrusion is still not free from a measure of "mythology," and that while the exposure of this is one of the first tasks of scientific control, the danger of substituting "technical mythologies" for the older varieties cannot be ignored.

One of the factors affecting the surface finish of hot-rolled products is the soluble oils used in rolling, and Snow[27] has described comparative tests for the properties of rolling oils, including emulsion stability, wetting properties and staining. Even if sheet is produced from the rolls with satisfactory surface, it faces another hazard in heat-treatment, and Williams and Challis[28] have studied the staining of clad high-strength alloys in the salt bath. They show that staining is primarily associated with abnormal amounts of free alkali in the sodium nitrate, and demonstrate that the proportion of the impurity may be reduced to satisfactory levels by bubbling carbon dioxide through the molten salt.

At the Consumer's Works

Turning from the processes involved in the manufacture of semi-fabricated products to those applied by the user, Hinxman[29] has continued his valuable series of articles on the forming of sheet, covering both theoretical and practical aspects of spinning, deep drawing and pressing, drop-hammer forming, rubber-die pressing, stretch forming, hand forming and blanking and piercing. Special presswork techniques in the American aircraft industry have been described,[30] most of them applicable to aluminium alloys, and one of the most interesting is the use in large presses of the die-quenching technique following the hot forming of grids prefabricated from high-strength alloy plate. It is estimated that by this process, work previously requiring 24 man hours can be accomplished in eight minutes. Nevertheless, the cost of large presses is so high that even the American aircraft industry is chary of installing new equipment. In another paper[31] the development is noted in America of the radial-forming technique, the manufacture of contoured sheet components by rolling cone-shapes which are subsequently welded by the inert-gas-shielded arc process, the resulting "tube" being placed over an expanding mandrel and stretched to shape. The advantage of the technique is that maximum forming is obtained with least demand on elongation.

Yet another advance in the American aircraft industry is the use of honeycomb construction for doors and fuselage panels, and Dickinson[32] has described how a core of foil honeycomb, bonded with high-strength adhesive, is band-sawn to shape and joined to sheet-metal facings by muslin impregnated with a similar adhesive. The main advantages are claimed to be less weight, quicker manufacture and damping of mechanical vibrations. If the sluggard should go to the ant, why should not the faster-than-sound aeronaut learn from the bees!

One accompaniment of developing aircraft design has been the increasing amount of machining required in structures, and skin milling is an expensive and time-consuming aspect of this. Sanz[33] claims that "chem-milling" is a useful technique for this purpose, although as yet in an early stage of development. It consists of dissolving away in a controlled manner the metal not required, hot alkaline solutions being employed. One immediately fears an adverse effect on fatigue properties, but the author states that in fatigue a "chem-milled" sheet is, if anything, better than a conventionally milled one. The approach is interesting, but further detailed information will be required before any conclusion can be reached regarding the process.

Two articles have appeared on the fabrication of aluminium containers. That by Arend[34] is very brief and describes the production, on mechanised plant by seam-welding, of a "jerrycan" type of container for handling and transporting liquid foodstuffs. The author does not mention the alloy used, but gives details of the processes of cleaning, degreasing, forming, welding, and testing for pressure-tightness. The other paper[35] is concerned with the food containers of various shapes used in the school meals service: these are made from aluminium—1¼% manganese alloy (NS3) with rims on the cylindrical containers of aluminium-magnesium-silicon alloy (HS10). Design presented several problems, all the containers being double skinned for insulation, and manufacture includes rolling of cylinders, flanging and pressing operations, and inert-gas-shielded arc welding. Similar operations, on a much larger scale, are involved in the production of chemical plant and vessels, and a well-equipped factory concerned with this work has been described.[36]

For many years, the very best cars have had bodies made from aluminium sheet by coach building, and, more recently, less high-class vehicles have attained weight reduction by having aluminium alloy bonnets, boot lids, doors, etc. This country has yet to see, however, a mass-produced all-aluminium alloy body, for although most of the technical problems are solved, first cost is still higher than that of the steel body. Much interest, therefore, attaches to Slade's[37] account of the production in France of the Dyna Panhard 54 in aluminium-magnesium alloy, by methods very similar to those used in steel construction. Pressing and spot-welding are described, and the author concludes that the body is a fine engineering achievement, although in his view still further developments are necessary in spot-welding equipment for aluminium alloys to obtain more efficient assembly.

Joining

Riveting, Soldering and Resistance Welding

A very large proportion of industrial effort is concerned with joining things together, and as the applications of a material become bigger, so larger joints introduce larger problems. The difficulties associated with large joints in aluminium and its alloys have been vigorously tackled since the war, and Brace[38] has recalled that it was only in 1948 that serious work was commenced on the development of large aluminium alloy rivets, and yet he shows that the investigations have been so successful that rivets up to ⅞ in. diameter are now being

used in both shop and field, with a variety of manufactured heads and driven points, and cites a number of recent large structures which have been fabricated with such rivets. Brace refers in his paper to the antiquity of riveting, and in contrast another method of joining aluminium is an upstart, having been available for only just over a decade, namely, adhesive bonding. Johnson[39] in this country and Simons[40] in America have described metal adhesives, and both give tabular guidance to the choice of suitable grades for bonding metals to each other and to non-metals. Johnson mentions honeycomb structures, the use of which in the American aircraft industry is noted above, and predicts wide-spread civilian applications for them. It is useful to have Simon's thoughts on the shortcomings of glued joints, and some indications of when to glue and when to use more conventional joining methods; the chief drawback seems to be the poor strength of adhesive-bonded joints when loaded in the "peeling" direction.

Despite the fact that soldering methods for aluminium were proposed before Hall & Heroult made their discoveries, this method of joining has remained full of difficulties, not only in technique but in subsequent joint behaviour. Many an investigator, surveying a soldered joint in aluminium, fallen apart after a few hours in boiling water, must have felt sympathy with Arthur when, after that last big battle at Lyonnesse, he told Bedivere that "the sequel of today unsolders all." The last year or two have seen a little sanity introduced and Dowd[41] has surveyed the present position. His method of illustrating potential relationship in soldered joints is simple and clear, by means of plotting electrode potentials against geometric positions across the joint. Bailey and Hirschfield[42] have also published a survey of progress, and include a range of solders and the results of strength tests on soldered joints. They also emphasise the importance of choosing a solder which does not promote electrolytic corrosion, or, alternatively, of providing very efficient protection for the joint.

Another joining method for aluminium that has only received attention fairly recently is cold pressure welding. In a general and comprehensive article on pressure welding, both cold and warm, Tylecote[43] has described the joining of aluminium to itself and to copper, iron, and nickel, while Hughes[44] has done similar work with rod specimens. Unfortunately it is not possible to compare the deformation values for mixed joints in these two papers, since Tylecote measures them for welds "as strong as between two pieces of aluminium" while Hughes refers to "strong joints," and his figures are consistently higher. Both papers are very informative, that of Tylecote being the most all-embracing yet published on the general subject. It is in the *British Welding Journal*, which first appeared in 1954 and which has had an enthusiastic reception.

Resistance spot-welding of aluminium alloys is well-established, notably in aircraft construction. Dixon[45] has reviewed recent advances, particularly in equipment, in a very concise article, and notes that the absence in this country of a specification concerning the spot-welding of light alloys, such as is issued by the American National Military Establishment, has probably restricted the application of this method of joining in the British aircraft industry. Dixon[46] (with Roberts) has also described an investigation into the spot-welding of high-strength clad aluminium alloy sheets to D.T.D.610B and D.T.D. 687, with particular attention to shear strength consistency and the incidence of weld cracking. After studying the effect of many welding variables, the authors are able to recommend conditions for the production of reproducible satisfactory welds in both alloys. There is a resurgence of interest in the United States in the use of single-phase equipment for spot-welding aluminium alloy sheet, and articles have appeared by Johnson,[47] by Kehoe and McCutcheon,[48] and by Harris.[49] Slope control is used to simulate the wave shape of stored energy welding equipment, and from the three accounts may be culled welding conditions for several alloys, with and without forging pressure, and all producing results conforming to the specification Mil-W-6860 which Dixon mentions.

Roberts [50] has reviewed the literature on the spot-welding of coated steels, and includes some information about aluminium-clad steel sheet. The references are not numerous, and there seem to be differences of opinion as to technique, particularly as regards methods of cleaning before welding.

Fusion Welding

The inert-gas-shielded arc-welding process is a fruitful field for the research worker, especially if he has a bent for electrical engineering, and during the past year several papers have been published which are of indirect interest to the aluminium metallurgist, who depends so much on these methods of welding. Needham and Hull[51] have studied the self-adjusting characteristics of shielded welding arcs, by comparing as sources a commercial D.C. welding generator, with steeply drooping output characteristic, and low-voltage D.C. and A.C. sources with nearly flat characteristics. They describe methods of estimating the degree of self-adjustment. In the development of the Filler-arc consumable-electrode method of welding, Tuthill[52] studied the effects of variables on arc characteristics, and has now published curves relating the voltage across the arc to wire feed speeds and currents for various metals, including aluminium. Helmbrecht and Hackman[53] have also studied power effects on consumable-electrode welding, and conclude that constant potential operation is to be preferred, particularly for positional welding of aluminium.

With the widening field of application of inert-gas-shielded tungsten-arc welding, and the increasing number of metals involved, considerable thought and experience is necessary to select the best equipment and operating method for the job in hand. Huff[54] has considered the merits of helium and argon, of plain, thoriated and zirconiated tungsten electrodes, and of various welding currents for different metals, including aluminium, and one of his recommendations is that high-purity helium is the best gas for the high-speed welding of aluminium—a conclusion of theoretical interest only in this country. Lavelle[55] has gone into the selection of the best conditions for this type of welding in great detail, and in the form of a series of questions and answers. He seems to prefer argon for aluminium, but notes the advantages of helium for mechanised welding due to the greater heat transfer through the arc. This author devotes much space to the importance of protecting personnel against radiation, and this danger has also attracted the attention of a Committee of the British Welding Research Association, which has published useful recommendations[56] for protective measures, including special clothing and eye-shielding filters. Silverman and Gilbert[57] have

carried out laboratory and field tests not only on the radiation danger, but into possible ill-effects from gases produced in welding. With aluminium, they conclude that the only danger is from silicon fume with alloys containing more than 5% silicon, and for these local ventilation should be used.

A very interesting account has appeared of development work by a British company[58] on the mechanisation of argon-arc welding for the production of a variety of fabrications, principally cylindrical in character. Most of the work is on alloys rather difficult to weld, including HS10, HS15 and unclad D.T.D. 687. The first of these is welded with the aluminium-11% silicon filler rod to eliminate cracking, the others being successfully welded autogenously. Details are given of speed of welding, current, argon flow, etc., for various alloys. Another mechanised process has been described by Donelan,[59] the "twin-argon" method for the manufacture of electric cable sheathing, involving two electrodes with a common weld pool. The author claims that this method has many advantages over conventional tungsten-arc welding, including better reproducibility and higher weld quality.

Brief descriptions have appeared earlier of the inert-gas-shielded metal-arc welding of the superstructure of the Thames pleasure launch *Queen Elizabeth*, but Houldcroft and Dixon [60] have now given a full technical account of the work and the difficulties encountered. This is interesting historically, as it was probably not only the first use in this country of this type of welding on a ship, but also the first time that alloy NS5 had been joined by the consumable-electrode process outside the laboratory.

That which has been joined may also be put asunder, and Hull[61] has conducted *ad hoc* tests on the cutting of non-ferrous metals by the gas-shielded arc process, using both the tungsten- and metal-arc methods in the case of aluminium-5% magnesium alloy. He concludes that while the tungsten-arc method is successful, the self-adjusting arc is to be preferred, since the heat input is more concentrated and a narrower cut results.

Tomlinson[62] has provided a useful brief summary of the position reached in the welding of aluminium alloy structures. Chief place is naturally accorded to the inert-gas-shielded method, and a table is given of operating details for self-adjusting arc welding in NP5/6 plate. A particularly welcome item is a section on weld defects, their source and how to avoid them.

The staff of the British Welding Research Association have commenced the commendable task of publishing in serial form an account of the present position of their researches into the welding of aluminium and its alloys. At the end of the year they had already issued surveys of the literature on the fusion welding of heat-treatable alloys[63] and on weld cracking with particular reference to H10 type materials,[64] together with accounts of work on dilution in weld beads,[65] welding the high strength alloys,[66] and an application of mathematics to temperature distribution during welding.[67] When the series is complete, it will provide an up-to-the-minute account of an important aspect of welding research in this country.

Constitution

Investigators are continuing the protracted but vitally important task of adding to our fundamental knowledge of the alloys of aluminium, and Phillips[68] has followed his work on the aluminium-copper-silicon system with an account of his investigations into the aluminium-copper-iron series by methods of thermal analysis, microscopic examination and measurements of liquid solubility. He identifies a formidable range of constituents, including $CuAl_2$, $FeAl_3$, $MnAl_6$ and Cu_2FeAl_7, and lists five invariant points on the liquidus surface. The drawings of sections and surfaces of the ternary diagram reveal the complexity of the task of the worker in this field. In a brief note, Little[69] has described an examination of single crystals of a ternary compound of approximate composition $CrMg_{1\cdot5}Al_{12}$, which she concludes to be a member of a group of phases involving manganese, magnesium, iron and silicon, including a metastable phase $MnAl_{13}$, to which an addition of chromium lends stability as $CrMn_4Al_{65}$.

Properties

The hundredth anniversary of aluminium referred to earlier almost coincides with the fiftieth of Wilm's famous discovery, and although much ink has since been spilt on the subject, age-hardening is still not fully understood, and continues to fascinate investigators. Hardy has published further results of his work on aluminium-copper binary and more complex alloys; with Silcock and Heal[70] he describes a systematic X-ray study of high-purity binary alloys containing 2–4·5% copper, which were aged at temperatures varying from room temperature to 240° C. An ageing sequence of four different stages is demonstrated in accord with the classic work by Guinier and by Preston, and it is shown that the structures giving peak hardness vary according to the copper concentration and ageing temperature. Ageing curves at 110° C. are published separately,[71] and with them curves for alloys with small additions of tin or of indium, one effect of which is to shorten by about four-fifths the ageing time to peak hardness.

Extending the work on binary alloys to ternary aluminium-copper-magnesium alloys with fixed copper : magnesium weight ratios, Hardy[72] again draws ageing curves at various temperatures, and illustrates the effect on ageing of increased copper : magnesium ratio, which, he notes, could not have been predicted by extrapolation from the earlier results on binary alloys and those on ternary alloys with lower ratios. This work is based on Vickers hardness determinations, and no doubt the investigator will eventually extend it to X-ray studies as he has done with binary alloys.

Seeking a fresh method of increasing knowledge about the mechanism of ageing, Entwistle[73] has determined changes in damping capacity during ageing of quenched alloys, including high-purity binary alloys and ternary alloys with magnesium, copper and silicon, and some commercial materials. Theoretical explanations are discussed of the changes in damping capacity observed, but it is concluded that none are completely in accord with the experimental results.

The effects of elastic and of plastic strains applied immediately after quenching to an aluminium-copper-magnesium alloy have been investigated by Unckel.[74] He shows that elastic strains have little effect, but that plastic strain increases the eventual yield stress of aged specimens, as is known from experience in works practice on heat-treatable aluminium alloys.

Cook[75] and his co-workers have measured the Young's Modulus of cold-worked copper, brass and pure aluminium, and shown that the effect of cold-rolling deformation

on the first two metals is the progressive development of preferred orientation, accompanied by appreciable differences in elastic modulus in different directions of testing. With aluminium, however, due to its almost isotropic nature, this effect is much less pronounced, and high strains give a general lowering of the modulus.

Wrought alloys of aluminium based on additions of magnesium and silicon are a very important group commercially; although used to some extent without heat-treatment, they are principally heat-treated alloys, and compositions vary considerably throughout the world, and even within British specifications. A very important paper has been published by Harris and Varley,[76] assessing the factors which contribute to brittleness in fully-heat-treated aluminium-magnesium-silicon alloys of various types, and they conclude that with the varieties containing silicon in some (but not great) excess over that necessary to produce Mg_2Si, additions of manganese or of chromium are beneficial in inhibiting preferential grain-boundary precipitation during artificial ageing, and thus in avoiding brittleness. They also note that alloys with additions of copper and either chromium or manganese offer good strength and ductility. This work confirms results obtained from other sources, and may be expected to have its effect on commercial practice with these alloys.

Work has continued by various observers on the theory of creep, and pure aluminium is a popular material for experiment. Thus, Wilms[77] has extended his work with high-purity aluminium into the tertiary stage of creep, and found that there appears to be no basic modification of the deformation mechanism of secondary creep, except that structural changes become a result rather than a cause of the accelerated strain, and intercrystalline fissures make their appearance. Fazan[78] and his co-workers, applying McLean's techniques to pure aluminium, have shown that the contribution of grain-boundary shearing to creep strain follows the same primary and secondary stages as the total creep, and is independent of the test temperature. A functional relationship is given for this phenomenon. Further work on creep deformation in very pure aluminium at high temperature is reported by Chang and Grant,[79] using very coarse-grained material in order that the grain-boundary behaviour could be closely studied on the hot-stage microscope. At the temperature concerned, slip is still the fundamental mechanism of deformation, and the various effects of restraint on slip band formation are described and discussed, including the production of two types of sub-grain. Cell formation in high-purity aluminium has also been studied by Kelly and Gifkins,[80] by both microscopical and X-ray techniques; it is shown to follow, in some grains, the breakdown of kink and deformation bands, and also, at 300° C., to be independent of slip lines. The discussion in this paper reveals that while the various workers in this field are not yet in complete agreement as to creep mechanism, their minds are moving in the same general direction.

Attention in this work on creep mechanism is also devoted to aluminium alloys, and McLean and Farmer[81] have sought information about deformation characteristics in binary alloys made by additions of copper, of magnesium, and of zinc to high-purity aluminium. The main conclusions reached were similar to those with pure aluminium, except that the slip was distributed over many more planes, and all the alloys were more stress-resistive than the pure metal. Mullendore and Grant[82] have also studied high-purity aluminium-magnesium binary alloys, and perhaps their most striking finding is that, below 370° C., an addition of less than 1·0% of magnesium caused intercrystalline cracking in creep, while above that temperature cracking was prevented by recovery processes. At 200° C., the fracture of the alloy containing 5·1% magnesium was completely intercrystalline. An allied phenomenon has been observed by Sully and Hardy[83] with solution-treated and aged high-purity aluminium-copper alloys; creep at 190° C. occurred preferentially immediately on either side of grain boundaries, in areas depleted of copper, and all specimens failed without necking. Commercial-purity alloys had higher creep resistance, but still failed without necking unless over-aged at the high temperature of 300° C. Gregory and Grant[84] have sought an explanation, in terms of current theories of strengthening by a disperse phase, for the excellent high-temperature properties of sintered aluminium powder products. The best compliance with such theories is shown by short-time tests only, while the greatest benefits of the oxide phase are derived in long-term exposure, since the alloys are stable and do not lose strength by change in structure.

McKeown, Eborall and Lushey[85] have determined creep properties of 99·8%-pure aluminium (SIA) at 20, 50, 80, 250 and 450° C., as a basis for design stresses. The effect of grain size is shown to be marked at the two highest temperatures.

During 1954, a noble lord placed metallurgy on trial, the charge being fatigue failure in service. It is therefore reassuring to read in a general article on fatigue by Weck[86] that "where bad design and bad workmanship combine, failure is almost inevitable;" this author also points out that the addition of alloying elements is no substitute for "judicious changes in design, or (by) stricter adherence to the drawing in the machine shop."

Forsyth[87] has extended his work on fatigue in pure aluminium, comparing slip produced by static and by cyclic stressing. He concludes that cyclic stressing may produce a considerable rise in temperature in the region of slip bands, which becomes more localised at higher frequencies. This is most significant in view of the conclusions reached in a paper on the fatigue resistance of aircraft alloys. The development during and since the war of high-strength fully-heat-treated alloys has enabled stronger aircraft structures to be built, but, regrettably, increase in strength has not been accompanied by increase in fatigue resistance; thus the aluminium-zinc-magnesium-copper alloys of the D.T.D. 683 type are not much stronger in fatigue than the L65 aluminium-copper-magnesium alloy. Hanstock[88] has used damping capacity experiments to show that cyclic stressing of these alloys has similar effects to thermal over-ageing, causing precipitation and softening. In alloy D.T.D. 683 localised bands of precipitation have been found, in regions where fatigue cracks eventually form. This work emphasises the importance of ensuring that in aircraft structures the material is not stressed at values approaching the fatigue limit as found by laboratory tests. In a note on the effects on ductility of repeated tensile prestrain, Franz[89] includes an illustration of the microstructure of alloy 75S–T6 (similar to D.T.D. 683), showing slip-planes which are presumed to be delineated by preferential precipitation due to cyclic prestrain.

The fatigue strengths of fusion-welded joints in aluminium alloys have hitherto received inadequate attention, and the paper on the subject by Hartmann[90] and his co-workers is the more welcome. The most significant conclusion reported is that, for cycles in excess of a million, the fatigue strength of butt-welded joints is the same in all the alloys tested, namely aluminium-magnesium-silicon, aluminium-magnesium, clad aluminium-copper-magnesium, and aluminium-manganese alloys, all in plate form. The dressing of weld beads is held to be invariably beneficial for fatigue resistance, and smooth weld beads are better than rough.

It is often stated that the main difference between British and American technology is that here we make discoveries and ignore them, while across the Atlantic the original research of other countries is developed by manufacturing industry. Although we have had aluminium-magnesium alloys in this country for many years and made great use of them, when the B.S.I. published B.S.1500 : 1949, "Fusion Welded Pressure Vessels for Use in the Chemical and Allied Industries," there were large blanks where design data for aluminium alloys should have appeared (and, incidentally, for all non-ferrous metals). Now the Americans have only recently turned to aluminium-magnesium alloys, to take advantage of their weldability, but already we read[91] that alloy A548, aluminium-3½% magnesium, has been approved by the American Society of Mechanical Engineers for welded pressure vessels, and design stresses are laid down for this and for three other aluminium alloys. Custer[92] has described the destruction tests on welded A548 pressure vessels which led to this approval and to the design data being obtained.

Corrosion and Protection

Durability of metals is a quality which in many applications is of paramount importance, and the user will often tolerate many drawbacks to obtain this durability ; the established uses of so heavy and soft a metal as lead are evidence of this. If it were possible to be sure of the long life of aluminium in contact with all domestic supply waters, a vast new field for development of the metal would be opened. Wright and Godard[93] have studied in the laboratory the action of Kingston, Ontario, tap-water on commercial-purity aluminium and two alloys, and compared the effects with those of water taken direct from Lake Ontario. These waters are hard and slightly alkaline, and they both pit aluminium to only slightly differing degree in stationary contact, while neither do so if moving at more than about 7 ft./min. Unfortunately, no analyses of the waters are given, so that the effect of any copper content in the tap-water cannot be assessed ; one might assume from the results that there is no copper pick-up in the journey from the lake to the domestic sink. The original reason for the above work was that the investigators found the water a useful medium for comparing the resistance to pitting of different grades of aluminium, and Aziz and Godard[94] have reported tests using this water to study the effects of added silicon and added iron on the pitting corrosion of super-purity and 99·75% purity aluminium. Both silicon over 0·3% and iron increase the pitting probability and the pitting rate in super-purity metal, while up to 0·7% of either element has little effect on the 99·75% purity metal. At the same iron and silicon levels, the pitting probability is 2·5 times greater with the less-pure aluminium.

Service experience is always of prime importance in estimating the corrosion resistance of any metal in a particular environment, and this is especially so as regards exposure to severe atmospheric conditions. A useful article[95] has appeared which, after an introduction referring to the well-known A.S.T.M. exposure tests, goes on to cite six instances of successful application of aluminium roofing in particularly aggressive industrial atmospheres. A 21-ton railway mineral wagon, plated with aluminium in 1945, has recently been examined,[96] and found to be in excellent condition after use in an unpainted condition for carrying coal during the intervening years. Although areas "poulticed" with damp coal dust were noted, corrosion underneath was only very slight, and the wagon shows every sign of giving a very long service life.

Bleaching powder is a highly corrosive chemical, and rapidly attacks iron and steel. Cheng and Taeng[97] conclude from laboratory tests that, although some attack is experienced with aluminium and its alloys, the corrosion product is protective, and useful lives might be expected in service in bleaching powder plants.

Liddiard and Bell[98] have compared the stress-corrosion susceptibility of fully-heat-treated aluminium-copper-magnesium alloy (H15-WP) with normal and low manganese, and parallel and normal to the extrusion or rolling direction. Sheet suffered from stress-corrosion independently of direction of test, while extrusions were susceptible only in transverse tests ; this division was less marked with the low-manganese material. All specimens were fully protected if sprayed with aluminium or aluminium—1% zinc alloy.

The increasing use of the ultra-high-strength alloys in aircraft, particularly military aircraft, has drawn attention to the dangers of stress-corrosion cracking if unduly high stresses are by any means induced in structural parts. Service failures are very rare, but Hooker and Waisman[99] have cited case histories of failures in American aircraft due to this cause. They also discuss methods of avoiding conditions conducive to stress-corrosion cracking, particularly residual stresses, and possible surface protective treatments. Of these, none tested proved completely satisfactory and further work is in progress, including shot-peening to introduce compressive surface stresses.

The ever-increasing importance of fatigue resistance has lent interest to the investigation of corrosion fatigue, and Inglis and Larke[100] have shown that the endurance strength of a fully-heat-treated H10 type alloy in tap-water is about half that in air, and in 3% sodium chloride only a quarter. Correct painting was found in this case to be a very effective protection in all the conditions tested. Incidentally, the outstanding tensile properties these authors obtain in a manganese-bearing H10 alloy are one of the features of this paper.

A new chemical-dip process[101] has been announced for brightening aluminium, which has the advantage of being cheaper and easier to apply than either mechanical or electro-chemical polishing. The account gives full details of bath composition—a phosphoric acid : sulphuric acid : nitric acid : ferrous sulphate solution—and method of working, but little impression of the results produced, although these are, of course, difficult to describe.

Aluminium not only has a high corrosion resistance when used as pure metal or an alloy, but has wide applications in protecting other metals, either as a sprayed

coating or as paint. Heat-treated sprayed coatings afford scaling resistance to heated ferrous metals, and Sully[102] and his collaborators have shown that this treatment is only slightly inferior at 700° C. to chromising. Wray[103] has been testing aluminium paint for thirty years, and has written a memoir of this work which confirms the importance of the usual factors—correct preparation of the metal to be painted, correct paint formulation for the service conditions, correct application techniques. Even after his thirty years experience testing paint, both in the laboratory and by field tests, Wray still maintains that true assessment of the value of a paint depends on knowledge of its performance in service.

Applications

With the expanding application of aluminium and its alloys throughout the world, it is possible to record here only a representative selection of the interesting articles that have appeared. Although transport was an obvious and early field for aluminium, railway applications have been rather limited in this country ; however, the merits of lightening underground trains are now fully realised as a result of the L.T.E. aluminium train, and a British company has completed cars for the new Toronto Underground.[104] The eventual replacement of all London's trolley buses, and, as they wear out, of the existing internal-combustion-engined fleet, will be by double-deckers with aluminium alloy structure and sheeting. Full details have been published[105] of the alloys used in the prototype, together with some impression of the integral design. This method of design has also been applied to a lorry structure,[106] made in aluminium alloy by consumable-electrode argon-shielded welding, of 8 tons pay-load capacity, and, yet able to travel legally at 30 m.p.h. by virtue of an unladen weight below 3 tons.

The building and structural engineering industries are large consumers of aluminium, for both load-bearing and other components. A classic example of the advantage of aluminium alloy construction[107] occurred in 1954, when a well-known company wished to add a second storey to a building which was not designed for such an extension ; loads were kept to a minimum by making the upper storey as a portal frame in alloys H10 and NP5/6 by inert-gas metal-arc welding. The enormous aluminium alloy doors of aircraft hangars are becoming almost commonplace, and four pairs of the Templex variety have been installed at London airport,[108] each in two halves and stretching across an opening 46 ft. high × 300 ft. long ; 195 tons of aluminium alloy were used to make the four doors, the structure being in HE10 and the corrugated sheet in NS3. The cladding of skyscraper structures by conventional methods is much too slow for the Americans, and they have developed aluminium sheathing panels,[109] with aluminium windows, by means of which a 26 storey office building in New York was finished off in 6½ days. Aluminium statuary and memorials are becoming popular, following the good example set by Eros, and the Australian-American war memorial at Canberra,[110] unveiled by Her Majesty the Queen on February 16th, 1954, is an octagonal aluminium-covered shaft 258 ft. high, surmounted by a sphere and the American bald eagle, also both in aluminium.

Turning to applications of aluminium at sea, that beautiful vessel[111] H.M. Yacht *Britannia* has bridge structure and funnel in alloys HE10-WP, NE6 and NP5/6, joined with ½ in. and ⅝ in. cold-driven rivets in alloy N6. Dann[112] has described the manufacture of 21 in. torpedo tubes using alloys N5, H10-WP, LM6-M and LM10-W, by argon-arc welding and riveting. He expects future designs to be welded throughout. An easy way of boarding an oil tanker, or loading stores, is provided by an electrically operated hoist[113] which is pulled up the side by wire ropes, and rolls on the ship's hull on rubber tyred wheels. Instances have been assembled and reported[114] of the admirable seaworthiness of aluminium lifeboats, involving several cases of life-saving in heavy seas and also some deliberate ill-treatment to test resistance to damage by lowering under adverse conditions.

Summaries of the position reached in various markets by aluminium and its alloys are valuable to the salesman and the technologist, and Nuttall[115] has described most clearly the applications of aluminium and its alloys in a series of industries, all of which deal with chemicals and food. In some of these aluminium is well represented while in others, notably the dairying industry, one feels that the future holds possibilities for considerable increase in aluminium usage. Roylance[116] has performed a similar service as regards textile equipment, and here the variety of aluminium alloy components, from the small pirn to the large warp beam, is impressive, particularly in such a first-cost-conscious branch of industry.

One of the papers presented at the Aluminium Centenary Congress in Paris was by Perkins[117] who surveyed aluminium applications in the U.S.A. It is interesting to have this information for comparison with uses here, although the volume is, of course, much greater in America—thus, as an example, 42,500 short tons of foil were used in 1952. The emphasis on domestic applications in Perkins' paper points a way for this country, although some of the American goods mentioned, whether of aluminium or not, are probably saleable in volume only in a country with a very high standard of living.

Standardisation

The importance of standardisation is being increasingly realised in industry, and the series B.S.1470–1477 for wrought products and B.S.1490 for ingots and castings continue to provide an invaluable basis for the development of fabricated products involving aluminium and its alloys, which in turn are themselves standardised after the necessary period of experience. West[118] has recalled the history of these basic standards, and urged yet again that the nomenclature they offer should be used on drawings to the exclusion of other designations which can cause confusion. Current light alloy specifications have been summarised,[119] including those for aircraft and those for general engineering ; this forms a very handy document for rapid reference, and it also has a section covering all British Standards in which reference is made to aluminium.

Although to some extent the more popular aluminium alloys are in use in most industrial countries, the details of standard materials vary considerably and Smith[120] has performed a herculean task in comparing standards for aluminium casting alloys in this country and overseas, not only as regards composition and properties, but also with reference to test pieces and testing and the marking of ingots and castings.

New standards concerning aluminium issued during the year were not numerous, although work on standardisation has continued to progress. Fixing accessories such as hook bolts, drive screws, washers, etc., for aluminium roofing and siding are now standardised,[121] and there is extensive reference to aluminium and its alloys in the new standard for builder's hardware.[122] Standards for weft pirns[123] for various trades within the textile industry have been issued, but the task is not yet complete. The success of aluminium-sheathed power cables has been crowned by a new issue of B.S.1480,[124] covering these cables for use up to 22kV.

Lastly, and with tongue in cheek. While welcoming a British Standard[125] for layout of periodicals, the inveterate reader of journals regrets that it does not prohibit that bane of his kind, the article which runs from Page 29 to 37, and then has its last paragraph on Page 58, or even Page 16. In this regret he is joined by the librarian, short of filing space, who wishes to cut out the articles and finds that she has four sheets and a piece about the size of a postage stamp which, moreover, has on its other side part of yet another article which she would like to keep. Probably it is unavoidable, just as quite short articles seem to have to be serialised, but it is not conducive to the equanimity of either reader or librarian. Perhaps it should be hastily added that one's present host is quite satisfactory in these respects!

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Aluminium on the 'Big Dipper'

WHEN the tower of Blackpool's popular switchback, the 'Big Dipper,' was rebuilt recently after destruction by fire, aluminium was used for certain features on account of its lightness, resistance to corrosion by sea air and, not least, its bright appearance, which accords well with the modern, sophisticated architecture of the rest of the Pleasure Beach.

The most striking of these features is a decorative 'sphere' situated at the top of the tower over 70 ft. above ground level and visible fifty miles away when lit up. It comprises six 18-ft.-diameter discs set star-wise and bolted at their vertical diameters to a common upright which consists of a cylinder 19 ft high by 3 ft. 6 in. diameter containing an aluminium ladder to permit examination and maintenance. The vanes were designed to withstand wind loads of up to 40 lb./sq. ft., and before erection they were tested to this loading with the aid of sand.

Below the decorative feature is an aluminium parapet about 3 ft. 6 in. high, curved in plan to a radius of 17 ft. 6 in. It encloses the track at the point where carriages, having ascended for the run, swing round to make their first descent, and carries vertical strips of neon lighting. The parapet, like the 'sphere', had to be designed to withstand the severe gales that are experienced on the coast.

Over the main entrance, at the base of the tower, has been built an aluminium domed roof 55 ft. in diameter and weighing 3¼ tons. It is carried on eleven wooden cantilever brackets and is also supported by a wooden canopy over a side entrance. Owing to its extreme lightness, the load it puts on the supports is negligible. As an extension to the roof, and for most of its circumference, is built a cantilever canopy of aeroplane wing design, presenting an unobstructed underside and, with the main roof, creating a general impression of simplicity and lightness.

The materials used were Noral 51 S WP extruded sections and Noral 3 S¼H sheet, 16 s.w.g. on the roof and 20 s.w.g. elsewhere. The architect was Joseph Emberton, F.R.I.B.A. and the structural design, fabrication and erection were by Aluminium Construction, Ltd., Woking.

As the new structure is very close to the promenade it is directly exposed to the salt-laden winds, and possibly salt spray, blowing in from the Irish Sea. There is confidence, however, that the aluminium, unpainted as it is, will withstand such rigorous conditions over many years with little need of maintenance.

THE name of Stand, Ltd., London correspondent for the Aluminium, Ltd., Group of Companies, has been changed to Aluminium (Canada), Ltd.

Aluminium in the Oil Industry

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In certain sections of the oil industry, the high thermal conductivity of aluminium alloys may be equally as important as their lightness and durability. In the present article, the author pays particular attention to the problems involved in the use of these materials in pipe lines. Reference is also made to aluminium alloy tanks and containers.

IN this review of the use in the oil industry of wrought aluminium alloy in the form of sheet, strip, plate, tube and extruded section, general research and experimental progress which might be of value to the industry will be considered, along with recent applications of light alloys in this field. The ever-increasing number of new applications is an indication of the ability of aluminium and its alloys to satisfy the varied conditions of service arising in many industries in this country and abroad.

Although aluminium alloys are mainly used because of their lightness, strength, durability and welding properties, they have other attractive characteristics which are, perhaps, not so widely appreciated. These include high heat reflectivity, high thermal conductivity, and strength at low temperatures. For example, the "U" or thermal transmittance value, expressed as B.Th.U./sq. ft./hr./° F. is of the order of 0·5–0·52 for 20 s.w.g. corrugated aluminium alloy to NS3 (B.S. 1470), as compared with a value of 1·2–1·5 for $\frac{1}{16}$ in. thick galvanised steel. This property ensures that aluminium-clad buildings are cooler in the tropics and warmer in colder regions, and is an important factor when plant insulation is considered. The thermal conductivity of aluminium alloys ranges from 0·54 to 0·57 C.G.S. units, whereas the comparative value for mild steel is of the order of 0·11 C.G.S. units.

One of the important points which has emerged from the use of aluminium piping in heat exchangers and condensers is that, besides having a high thermal conductivity—which is important in itself—aluminium retains this property in service, owing to the absence of an increasing insulating layer of rust and scale which is so often experienced with steel. In practice, therefore, the superiority over steel is even greater than the foregoing figures suggest.

Aluminium Plain End Pipe Lines

In considering the use of any metal, the problem of efficient jointing must be solved before bulk usage can be developed. It is interesting to note, therefore, the work that has recently been carried out in connection with the proposed use of aluminium oil pipe lines. Consideration was given to providing an aluminium plain end pipe having the necessary characteristics as required by the American Petroleum Institute Specification A.P.I.5L for Grade B steel. The problem was considered from two aspects: firstly, to ascertain the type of pipe and the wall thickness necessary to meet the required conditions; and secondly, to develop a welding technique which would join the piping in an efficient manner—the efficiency of the welding technique to be evaluated by pressure testing of the butt-welded pipe in comparison with a pressure test to destruction of the unwelded pipe.

TABLE I.—SPECIFIED CHEMICAL COMPOSITION OF HT10-WP—B.S.1471

Element	Cu	Mg	Si	Fe	Mn	Cr	Al
Content %	0·15 max.	0·4–1·5	0·75–1·5	0·6 max.	1·0 max.	0·5 max.	Remainder

TABLE II.—SPECIFIED MECHANICAL PROPERTIES OF HT10-WP—B.S.1471 (WALL THICKNESS OVER 16 S.W.G.)

0·1% Proof Stress	Ultimate Tensile Stress	Elongation
15 tons/sq. in. minimum	19 tons/sq. in. minimum	9% minimum

In view of the successful work already carried out abroad in connection with experimental installation of pipe lines, it was decided to use a magnesium-silicide type of alloy, corresponding to HT10–WP (B.S. 1471), which has a high proof stress, good corrosion resistance, and suitable welding characteristics. The specified chemical composition and mechanical properties are given in Tables I and II, but bulk testing has indicated that typical mechanical properties of the alloy in pipe form are usually some 7–10% higher than the specification requirements. It was ascertained that a range of sizes up to $10\frac{3}{4}$ in. O.D., in lengths of 20 ft. maximum, could readily be made available in the form of extruded, cold-drawn and heat-treated pipe having the specified properties, so consideration was given to the further problems associated with pressure testing requirements and welding procedures.

In assessing the wall thickness necessary to withstand the hydrostatic test specified in Section 5 of the A.P.I. specification, a fibre stress value equivalent to 60% of the specified minimum yield stress is used. Light alloys have no yield stress, in the sense that mild steel has, but the 0·2% proof stress may be regarded as equivalent to the yield stress, the respective figures for HT10–WP and Grade B steel being 16 tons/sq.in. and 35,000 lb./sq.in. (15·6 tons/sq.in.)

The formula used in calculations concerning the test pressures applied to plain end pipe $3\frac{1}{2}$ in. O.D. and larger is:

$$P = \frac{2St}{D} \text{ or } 2{,}500 \text{ (whichever is smaller.)}$$

Where P = hydrostatic test pressure in lb./sq.in.
S = fibre stress in lb./sq.in.
t = tabulated wall thickness in in.
D = tabulated outside diameter in in.

A schedule showing outside diameter, nominal bore size, wall thickness, weight per unit foot and test pressure based on the above formula, with a value of 21,000 lb./sq.in. for S—is set out for aluminium alloys in Table III. The values for steel are approximately the same, so that with the same diameter and wall thickness as for

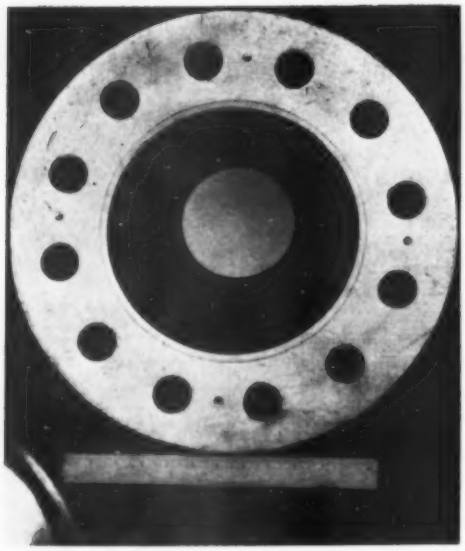


Fig. 1.—10 in. I.D. butt welded pipe showing the small bore restriction caused by the weld penetration bead.

steel piping, the light alloy product will withstand the test pressures specified in specification A.P.I.5L, with the same factor of safety. In other words, full advantage can be taken of the difference in specific gravity of the two metals, and the weight per foot of the aluminium pipe is roughly one-third that of the equivalent steel pipe.

On the manufacturing side, no difficulties are to be expected on the question of tolerances, as the processes involved are capable of making a product which will satisfy the tolerances specified for steel. Therefore, no great variation in weight or thickness should be experienced from this cause.

Field experience, in confirmation of laboratory tests, has indicated a high resistance to corrosion by petroleum products. This is of considerable importance in pipe lines, as it allows the bore to remain smooth and free from corrosion products. Apart from preventing contamination of the oil product, the full bore of the pipe is available for conveying it. External durability of the pipe in marine atmospheres and salt water is a further advantage in this field, but, although aluminium is resistant to many types of soil, some degree of wrapped protection is necessary in most installations because of the wide range of conditions to be met.

Welding Techniques

Following consideration of the points discussed above, it was felt advisable to investigate pipe end preparation and welding techniques which could be applied to the jointing of piping in the field. The investigation was undertaken with the object of (*a*) developing the strongest joint with the minimum bore restriction (Fig. 1.); and (*b*) assessing the relationship between the strength of the pipe before and after butt welding.

The unwelded test samples of the 10 in. I.D. pipe were cut to a length of 3 ft., and the welded samples finished the same length with the butt weld at the centre, in the case of the 3 in. I.D. pipe the unwelded samples were prepared 18 in. long, and the welded samples, were again of the same length, with the butt weld in the centre. The Argonarc process was the obvious choice for welding method, and the welding equipment used was the

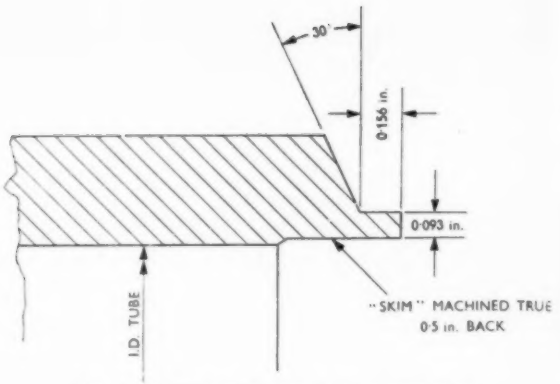


Fig. 2.—Sketch showing joint preparation.

British Oxygen Company's Type C.P.U. 300Q Power Unit in conjunction with their NK.3 III torch.

During preliminary consideration of pipe end preparation prior to welding, it was decided to use the form which had been developed for other purposes during earlier work. The reason for the choice was that welding could be carried out in all positions without the use of any internal backing bar or strip: a sketch showing the form employed is given in Fig. 2. Using this method it is essential that the thickness of the root face should be constant for the test programme: a condition which was satisfied by skimming through for $\frac{1}{2}$ in. from the ends to be welded. The particulars of the welding procedure employed are set out in Table IV.

Welding was carried out in the downhand position, the pipes being tacked and aligned in close-fitting condition: one tack was used. Welding proper commenced from a point diametrically opposed to the tack,

TABLE III.—REGULAR WEIGHT PLAIN END PIPE LINE TO TABLE 6, GRADE B. DIMENSIONS, WEIGHTS AND TEST PRESSURES*

Outside Diameter in.	Weight lb./ft.	Wall Thickness in.	Inside Diameter in.	Test Pressure lb./sq. in.
3½	2·30	0·188	3·124	2,200
	2·62	0·216	3·068	2,500
	3·00	0·250	3·000	2,500
	3·36	0·281	2·938	2,500
4½	3·00	0·188	4·124	1,800
	3·47	0·219	4·062	2,000
	3·61	0·237	4·026	2,200
	3·92	0·250	4·000	2,300
	4·36	0·281	3·938	2,500
	4·77	0·312	3·876	2,500
6⅝	4·46	0·188	6·249	1,200
	5·15	0·219	6·187	1,400
	5·86	0·250	6·125	1,600
	6·54	0·280	6·065	1,800
	7·25	0·312	6·001	2,000
	7·95	0·344	5·937	2,200
	8·62	0·375	5·875	2,400
8⅝	5·82	0·188	8·249	900
	6·78	0·219	8·187	1,100
	7·69	0·250	8·125	1,200
	8·50	0·277	8·071	1,300
	9·55	0·312	8·001	1,500
	9·85	0·322	7·981	1,600
	10·58	0·344	7·937	1,700
	11·50	0·375	7·875	1,800
	13·30	0·438	7·749	2,100
10¾	8·46	0·219	10·312	850
	9·69	0·250	10·250	1,000
	10·83	0·279	10·192	1,200
	11·90	0·307	10·136	1,200
	13·30	0·344	10·062	1,300
	14·03	0·365	10·020	1,400
	16·75	0·438	9·874	1,700

* From American Petroleum Institute Specification A.P.I. 5L.
The test pressures for similar pipes in Grade B steel and HT10–WP aluminium alloy are the same.

Fig. 3.—3 in. I.D. plain pipe. Steel reinforcing ring moved back to show circumferential tension failure at 5,600 lb./sq. in.

Fig. 4.—10 in. I.D. plain pipe fitted with reinforcing rings, showing location of failure at 2,500 lb./sq. in.

and was carried out in steps, starting at the 10 o'clock position and finishing at the 2 o'clock position, the pipe being rotated for re-starting at the 10 o'clock position. It was found that in the case of the 10 in. I.D. pipe two runs were just sufficient to fill the joint, but since reinforcement was considered advisable, a further run was added.

It will be noted from Table IV that the filler wire was of the aluminium—5% magnesium type, the reason being that this material has a high measure of strength in the cast condition.

TABLE IV.—DETAILS OF WELDING PROCEDURE

Specimen	Welding Current amp.	Argon Flow cu. ft./hr.	Shield Size	Tungsten Diameter in.	Filler Wire* Diameter in.	No. of Run
48/C/4 ..	208	18	2	1/8	1/8	1st
	225	18	2	1/8	1/8	2nd
	225	18	2	1/8	1/8	3rd
48/C/5 ..	205	18	2	3/16	1/8	1st
	205	18	2	3/16	3/16	2nd
48/C/8 ..	205	18	2	3/16	1/8	1st
	205	18	2	3/16	3/16	2nd

The filler wire was aluminium—5% magnesium alloy.

TABLE V.—PRESSURE AND MODE OF FAILURE OF TEST PIPES

Specimen	Size in. I.D.	No. of Runs if Welded	Pressure at Failure lb./sq. in.	Mode of Failure
48/C/4 ..	10	3	2,100	Triangular tear through weld.
48/C/15 ..	10	—	1,600	Through end fillet, 3/4 in. length.
48/C/16 ..	10	—	2,500	Longitudinal tear terminating at steel reinforcing rings.
48/C/5 ..	3	2	4,000	Split through softened zone above fillet.
48/C/8 ..	3	2	3,600	Failed through defect in flange material.
48/C/17 ..	3	—	4,400	Failed through softened zone above fillet.
48/C/18 ..	3	—	5,600	Failed circumferentially under steel reinforcing ring.

Testing Procedure

Pressure Testing

In order that the full effect of the longitudinal and hoop stresses could be observed, flanges were welded to each end of every test piece to enable the ends to be blanked off for pressure testing. To prevent trouble in sealing, the ends of the test samples were blanked off with welded light alloy plates: the blanking off can be seen in Fig. 3. The pressure tapping was welded into one of the blanking plates, and since the blanking plate was then compared to the flanges the steel flange cover plates were retained as stiffeners for the purpose of the test. As testing proceeded it was found that the pipes which had not been butt welded were failing through the heat softened zone adjacent to the flange fillet welds. In order to prevent over-straining at these points, steel reinforcement rings were prepared, which fitted tightly around the pipes at the softened zones. In Fig. 3. the reinforcement rings are shown, one being pulled back to disclose the failure point.

Results

The failing pressures and modes of failure of the pipes tested are set out in Table V, together with the number of weld runs in the case of the butt welded pipes.

X-ray Examination

An X-ray examination was made of one 10 in. I.D. and one 3 in. I.D. welded pipe, but they were found to contain only isolated micro-porosity, coupled with scattered tungsten particles. It was considered that both welds were well above normal commercial standards.

Discussion of Results

The pressure tests to destruction indicate that the unwelded pipe will satisfy the conditions of the A.P.I. 5L Specification, even when subjected to heat-softening brought about by the flange attachment. In the case of the 10 in. I.D. pipe with the use of reinforcing collars to restrict the circumferential strains at the softened zone, it will be noted that the pipe failure pressure was 2½ times the calculated value (Fig. 4.). Even when using reinforcement collars it was still not possible to destroy the 3 in. I.D. pipe in its fully heat-treated condition.

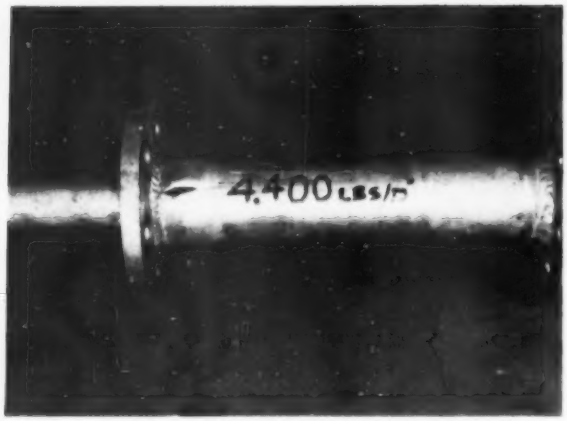


Fig. 5.—3 in. I.D. plain pipe showing location of failure at 4,400 lb./sq. in.

Failure occured as a circumferential tension break at the notch caused by the flange fillet (Fig. 5 and 6).

Butt welds in the pipe do not seriously affect the failing strength of the heat-treated pipe, and only in the case of the 10 in. I.D. pipe was it possible to cause failure in the weld zone (Fig. 7). The failing pressure of the weld zone on the 10 in. I.D. pipe was still above the calculated figure, and the break was almost certainly initiated at a point where machining had notched the internal surface of the pipe.

It will be appreciated that the welding method adopted would facilitate overhead welding, which should be of value in the field and give a uniform internal bead. Should, however, it be desired to use a single bevel preparation, this could be achieved by using the normal practice in pipe welding; i.e., a collapsible backing ring. It is not anticipated that the same high weld efficiency would be obtained, although the joint would probably be satisfactory in service in view of the high strengths obtained in the present welding programme.

From the general standpoint, the welding investigation proved that the piping in the HT10–WP alloy can be readily welded by the Argonarc process, thus eliminating corrosive fluxes, and that there is no subsequent necessity to clean, chip or finish the weld in any way. The pipe can be welded with plain uncoated filler rod which can be stored under the same conditions as other metal products, without additional precautions, even in the tropics. None of the difficulties associated with moisture-absorbent flux-coated filler rods, which can cause inferior welds, are likely to be experienced.

Plate Welding

Any important advances in the art and science of welding plates should, it is thought, be of interest to the petroleum industry, particularly in connection with the large welded tanks and structure which are extensively used. The following work, therefore, is described to illustrate the advantages of the consumable-electrode process over the Argonarc method when welding certain thicknesses of plate.

An investigation has recently been made into the inert-gas-shielded welding of HP10 and NP5 6 alloys to ascertain the effects of using various filler wires and welding speeds on the strength and elongation values of butt welds. In general, it was noted the the consumable electrode process produced test plates giving tensile

TABLE VI.—MECHANICAL TEST RESULTS ON ARGONARC BUTT WELDS IN 0·3 IN. THICK HP10 PLATE

Filler Wire	Preparation	Speed in./min. (No. of runs)	0·1% Proof Stress tons/sq. in.	Ultimate Tensile Stress tons/sq. in.	Elongation %	Bend Test	Fracture	State of Specimen
Test Plates in the "As Welded" Condition								
NW6	SB	2½ (1)	6·0	10·9	13	°	PM	U
			4·4	10·2	16	45°	PM	T
NW6	90° vee ⅛ in. RF	2½ (1)	5·7	10·6	14		PM	U
			3·6	10·2	15	45°	PM	T
NW6	90° vee ⅛ in. RF	3 (2)	6·5	11·3	12		PM	U
			5·8	10·8	15	52°	PM	T
NW21	90° vee ⅛ in. RF	3 (1)	6·0	10·9	11		PM	U
			4·7	10·6	12	25°	PM	T
Test Plates Aged After Welding								
NW6	SB	2½ (1)	7·0	11·0	12		PM	U
			6·5	10·6	12	45°	PM	T
NW6	90° vee ⅛ in. RF	2½ (1)	6·8	10·7	13		PM	U
			6·3	10·5	13	13°	PM	T
NW6	90° vee ⅛ in. RF	3 (2)	7·0	11·2	12		PM	U
			5·1	10·8	13	25°	PM	T
NW21	90° vee ⅛ in. RF	3 (1)	6·6	11·1	12		PM	U
			6·5	11·0	11·5	10°	PM	T

SB—Square butt preparation.
RF—Root face (the abutting face of the plate edge).
PM—Fracture originating in the parent metal.
I—Fracture originating at the interface between weld metal and parent metal.
W—Fracture originating in the weld.
T—Specimens tested with the weld reinforcement removed.
U—Specimens tested with the weld reinforcement untouched.

properties which were usually better than those obtained from test plates produced using the Argonarc process. It was found inadvisable to use the HW10 filler wire for the Argonarc welding of HP10 plate because of the danger of cracking. The NW6 filler wire gave more ductile welds than NW21 filler wire, and these welds were also found to be sounder. With the consumable electrode welding method, however, no cracks occurred when

Fig. 6.—3 in. I.D. butt welded pipe showing: left—location of failure at 4,000 lb./sq. in.; right—permanent set which occurred before flange failed at 3,600 lb./sq. in.

TABLE VII.—MECHANICAL TEST RESULTS ON BUTT WELDS IN 0·3 IN. THICK HP10 PLATE MADE BY THE INERT-GAS-SHIELDED CONSUMABLE-ELECTRODE PROCESS

Filler Wire	Preparation	Speed in./min. (No. of runs)	0·1% Proof Stress tons/sq. in.	Ultimate Tensile Stress tons/sq. in.	Elongation %	Bend Test	Fracture	State of Specimen
Test Plates in the "As Welded" Condition.								
HW10	90° vee $\frac{3}{8}$ in. RF	26 (1)	8·4	14·1	9		1/PM	U
			7·5	14·1	10	45°	1/PM	T
NW6	60° vee 0·15in. RF	22 (1)	8·3	15·1	6		1	U
			8·9	15·1	12	20°	1/PM	T
NW21	SB	22 (1)	7·1	13·2	8		W	U
			8·2	13·2	7	20°	W	T
Test Plates Aged After Welding								
HW10	90° vee $\frac{3}{8}$ in. RF	26 (1)	14·2	17·3	4		1	U
			13·2	16·9	5	10°	1	T
NW6	60° vee 0·15in. RF	22 (1)	10·1	15·0	7		1/W	U
			9·5	13·0	6	20°	1/W	T
NW21	SB	22 (1)	10·1	15·6	7		PM	U
			7·2	12·2	6	10°	W	T

TABLE VIII.—MECHANICAL TEST RESULTS ON BUTT WELDS IN 0·3 IN. THICK NP5/6 PLATE

Filler Wire	Preparation	Speed in./min. (No. of runs)	0·1% Proof Stress tons/sq. in.	Ultimate Tensile Stress tons/sq. in.	Elongation %	Bend Test	Fracture	State of Specimen
Argonarc Welds								
NW6	SB	3 (1)	6·9	18·0	18		1	U
			6·4	16·2	14	180°	W	T
NW6	SB	4 (1)	6·0	17·9	19		1	U
			5·1	13·1	13	180°	W	T
NW6	60° vee $\frac{3}{8}$ in. RF	3 (1)	7·1	18·0	19		1	U
			5·9	16·1	19	105°	W	T
NW6	90° vee $\frac{3}{8}$ in. RF	4 (2)	5·8	17·5	22		1/PM	U
			6·2	16·9	20	180°	W/I	T
NW21	60° vee $\frac{3}{8}$ in. RF	3 (1)	7·4	13·8	5		W	U
			7·3	14·1	4	10°	W	T
Consumable-Electrode Welds								
NW6	SB	20 (1)	7·8	16·7	12		1	U
			6·3	16·0	18	180°	W	T
NW6	90° vee 0·15in. RF	24 (1)	7·4	16·2	11		1	U
			4·1	15·4	15	180°	W	T
NW21	SB	24 (1)	6·7	14·9	4		1	U
			5·8	13·8	10	15°	W	T

HW10 electrode wire was used, and the mechanical test results were slightly better than those obtained when using NW6 wire. Tables VI, VII and VIII indicate the mechanical test results obtained with Argonarc butt welding of 0·3 in. thick HP10 plate, compared with the strengths obtained by welding the same thickness plate by the inert-gas-shielded consumable-electrode process, and in turn these are compared with the strengths of butt welds in 0·3 in. thick NP5/6 plate made by both processes.

Two main important factors emerge from this investigation which may be of interest to the oil industry: (*a*) it will be noted that for building large containers the consumable-electrode process, owing to its higher speed, gives higher strengths on both the HP10 and NP5/6 materials; and (*b*) from the economic standpoint it is interesting to note that the mechanical test results on butt welds in HP10 are at least as high, and in some instances higher, than those obtained with the more expensive NP5/6.

Aluminium/Steel Composite Piping

To meet certain requirements in the gas industry, an aluminium/steel composite pipe has been devised which may be of interest to oil engineers for use in heat

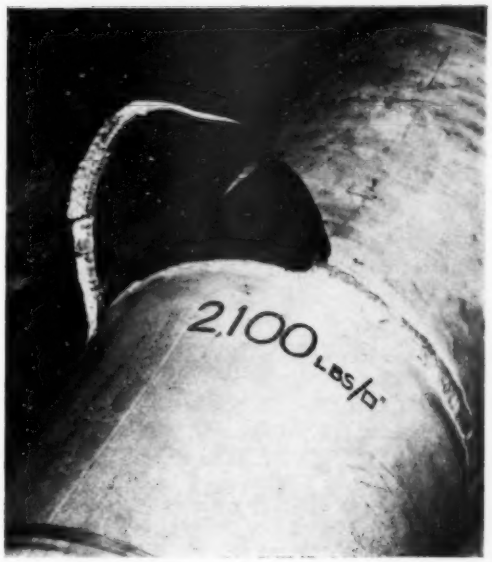


Fig. 7.—10 in. I.D. butt welded tube showing location of failure at 2,100 lb./sq. in.

exchangers and condensers. The attraction of the piping lies in the fact that it can be arranged so that both the aluminium and the steel are in contact with compatible media. The aluminium pipe can be in pure metal or any suitable alloy, and a mild steel or alloy steel tube can be used in conjunction with it. The steel pipe can be lined inside with aluminium, or an aluminium pipe lined inside with steel—according to the requirements of the application. Tubing from $\frac{5}{8}$ in. to 4 in. O.D. can be made readily available, and the wall thickness of the inner liner and outer sleeve can be varied within fairly wide limits to meet different requirements.

It is interesting to compare the thermal conductivities of stainless steel, mild steel and aluminium/mild steel composite piping. The value for stainless steel is 0·033–0·039 for mild steel 0·11, for aluminium/steel composite piping 0·18, and for aluminium alone 0·54 C.G.S. units. The corrosion resistance advantages of a bi-metal pipe can, therefore, be obtained with a higher thermal conductivity than mild steel, and an even greater difference is shown over the equivalent stainless steel pipe, which in some instances could be replaced by a composite pipe with considerable economic advantage.

The composite pipe can be bent to reasonably small radii with standard pipe-bending equipment, and the pipe ends can be coned, expanded or otherwise shaped, if this is necessary. Jointing is normally effected by expanding into a header plate, and such joints have been found easy of accomplishment and sound in service. Experience has been gained in town's gas manufacturing plants over the last twelve months, when the piping has given every satisfaction.

The primary advantages in the present application are the longer service life due to greater immunity from corrosion, and the reduction in plant shut-down-time and attendant loss of production occasioned by replacing condenser tubes. There is also higher and more continuous overall heat transfer efficiency—the thermal conductivity being about 50% greater than that of a normal steel pipe of the same thickness. Greater freedom

Fig. 8.—Screwed flush joint for drillable oil pipe. The taper thread can be seen faintly where the pipe is sectioned by the elongated hole.

from bore scaling allows an unrestricted flow of cooling water, and maintenance costs are reduced as periodic bore descaling is not needed.

It would appear that there are potential applications in the oil and petro-chemical industries, where resistance to corrosion and the prevention of the staining or discolouring of a product are important.

Drillable Oil Pipe

Supplies of drillable oil pipe have now been produced in this country in 4½ in. O.D. × 0·337 in. and 7 in. O.D. × 0·421 in. Fig 8 illustrates the type of screwed flush joint which is necessary with this type of piping. The value of light alloy piping on the well-boring side could be important from the weight-saving standpoint, as so many oil well installations are so far off the beaten track. It would be interesting to observe further developments in this field.

Aluminium in Seagoing Tankers

Recent reports in the technical press have indicated that tanker heater tubes in aluminium alloy have been successfully used over a period of several months without deterioration. If extended tests substantiate the claims that aluminium alloy piping will withstand the aggressive effects of heated crude oil and hot and cold seawater, then it would seem that there are many places in a tanker which are short-lived in service due to corrosion, which could be replaced with aluminium—if suitable care in design were observed, with sound but simple and effective insulation from other metals.

There is a potential application in tankers, then, not only for piping, but for many other structural parts where lightness is an important factor; but even this could be outweighed by the continued freedom from corrosion and the maintenance of strength of the part concerned. Every ton which can be saved in the structure of the vessel itself may result in a further ton of cargo being carried, so that the ultimate economies could be considerable.

Aluminium Alloy Drums

Aluminium alloy drums are now manufactured in increasingly large quantities from the magnesium containing alloys NS4 and NS6, and more recently in the 1¼% manganese alloy NS3. One very successful aluminium alloy drum is manufactured by rolling from sheet and welding by the Argonarc process, without using any filler rod. Two rolling rings are fitted which are of a steel top hat section contracted on to the drum and electrically arc welded. Drums manufactured by this method have withstood a drop test when filled 99·5% full with water and dropped on both end and side from a height of 4 ft. 6 in. on to a concrete floor. Drums manufactured from 14 s.w.g. sheet withstood 14 drop tests before leaking, which contrasts very favourably with steel drums which normally leak after 7 impacts.

It is interesting to note in connection with the potential application of these drums in the oil industry, that they are now being sold to convey fatty acids, glycerine, detergents and a wide variety of solvents. The continued cleanliness of the inside of the drum and its freedom from corrosion and staining of the product have been important factors in the growth of this usage.

General Progress

An attempt has been made to sketch briefly some of the research developments which might be usefully considered in the petroleum industry, together with details of suitable products recently developed—in some cases for other industries—which might be worthy of further consideration. From the standpoint of low temperature heat exchangers, it would seem that much progress could be made in this field where the properties of aluminium are so suitable in many situations.

In so many phases of the petroleum industry in exploration, extraction, transport, refining, and petro-chemical processing, the resistance of aluminium to corrosion by sulphur compounds and other typically aggressive agents, its light weight, its strength at normal and low temperatures, its good welding properties, and its excellent thermal conductivity and thermal transmittance values, engender a sense of optimism with regard to future developments.

Acknowledgments

The author wishes to express his thanks to Mr. C. L. Railton, Development Officer (Welding), Tube Investments, Ltd., Department of Development and Research, for his co-operation in connection with aluminium welding; to E. C. Payter & Co., Ltd., Great Bridge, for details concerning oil drums; and to T. I. Aluminium Ltd., for permission to publish certain information.

Increased Reamer Life

ENGLISH STEEL CORPORATION'S specially treated machine reamers, §in. in diameter, have been introduced for the reaming of connecting rod bolt holes at the works of one of the well known diesel engine makers in the United Kingdom. Life between reamer regrinding was previously 150–200 holes, with a total life of 900 holes, whilst the new reamers have produced 700–800 holes between regrinds with a total life of 3,100 holes.

Aluminium in Electrical Engineering

By J. C. Bailey, B.Sc., F.I.M.
The Aluminium Development Association

Great interest is now being taken in the use of aluminium in the electrical industry. In certain applications the technical merits are the important consideration, but in most cases, the main attraction is an economic one. In the following pages are discussed such applications as cable conductors, cable sheathing, bus-bars and windings.

ALUMINIUM has been of importance in electrical engineering since it first became commercially available towards the end of the nineteenth century. Records show that overhead conductors made in aluminium were put into use as early as 1898: this particular application of aluminium, where its light weight is of obvious advantage, has grown until today, all the principal transmission lines for electricity are fabricated in aluminium or steel-cored-aluminium. But it is only in recent years that the use of aluminium as a conductor material for general use in all types of electrical equipment has begun. The reasons for the rapid increase in the adoption of aluminium that is now occurring are mainly economic, but technical advantages are also being perceived.

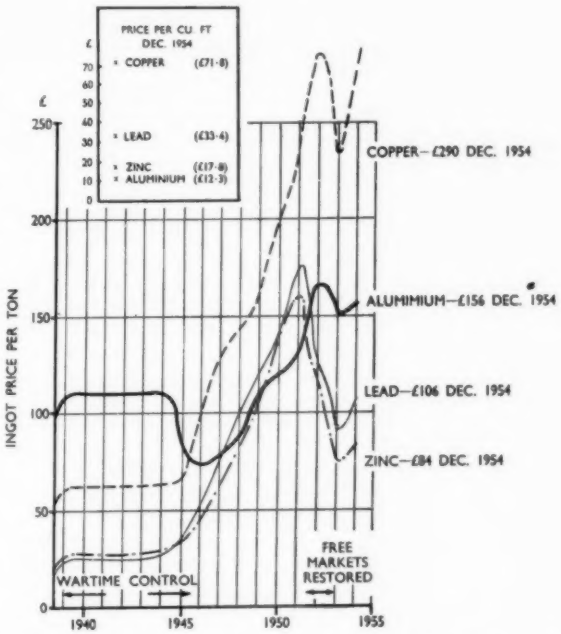
Economic Considerations

Table I shows that during the last twenty years, the output of the older non-ferrous metals—copper, zinc and lead—has not increased so rapidly in the U.K. as the total industrial output. This is a significant pointer, although the underlying reasons are not of immediate concern in the present argument. On the other hand, the rate of increase in output of aluminium far exceeds the rise in total industrial production, and is still accelerating. This should remove any lingering doubts regarding a future shortage of aluminium, whereas both copper and lead remain in constant danger of shortage as total demand continues its ever-upward trend. All this means, according to Murphy,[1] that aluminium will, in future, take an increasing share of the expansion in industrialisation. Thus, although copper is produced in greater quantities than ever before, yet output cannot keep pace with the demand. It may shortly become necessary, in the judgment of some suppliers, to confine the uses of copper to those applications where it is essential, and where, for technical reasons, no other conductor material could be used. In price also aluminium has assumed a very favourable position, and the uncertainty that has prevailed in recent years about the trend of non-ferrous metal prices is diminishing, following the restoration of free markets in the period 1951–1953. The graph shows the long-term trends, and also indicates

TABLE I.—INCREASE IN U.K. OUTPUT OF SEMI-FABRICATED NON-FERROUS METALS, 1938–1953*

Metal	Output		
	1938	1953	% Increase
Aluminium	46,000	215,000	350%
Copper	258,000	359,600	36%
Zinc	187,800	193,000	3%
Lead	389,000	303,750	—22%

* General rise in Index of Industrial Production 1937–1953: 50%.
* Data from various sources.



Price trends for non-ferrous metal ingots (figures quoted in December each year).

the advantageous position of aluminium, particularly when compared on a volume basis.

These considerations point to an ever-increasing use of aluminium in electrical engineering, where copper and lead have been used in the past: it is not surprising, therefore, to find members of the older non-ferrous metal industries installing plant for the production of semi-finished aluminium shapes, and in some cases actually undertaking primary production of aluminium. This trend is particularly apparent in the United States, but is also to be observed in Great Britain, and is in tacit agreement with the economic facts.

It is estimated that approximately 190,000 tons of copper are used every year for cables of varying types, along with 100,000 tons of lead. Equivalent figures for the electrical uses of aluminium are not available, but the figures in Table II show the increasing consumption of aluminium in Great Britain for conductors, and for wrought and cast components for electrical machinery and equipment.

After taking into account the difference in specific gravity between these three metals it is obvious that there is room for a vastly greater use of aluminium.

TABLE II.—ESTIMATED U.K. CONSUMPTION OF WROUGHT AND CAST ALUMINIUM IN ELECTRICAL CONDUCTORS AND EQUIPMENT

	Wrought (tons)	Cast (tons)	Total (tons)
1948..	3,600	4,800	8,400
1949..	5,700	3,800	9,500
1950..	6,000	4,600	10,600
1951..	7,100	6,200	13,300
1952..	10,600	7,000	17,600
1953..	8,000	5,900	13,900

Latin[2] estimates that 20,000 tons of aluminium could be used annually for cable sheathing alone.

From the economic aspect, aluminium is also often competitive with zinc-base alloy die castings, with malleable-iron castings, and with many copper alloy products such as stampings and castings. It is likely, therefore, to be increasingly used in apparatus involving these materials.

These weighty economic considerations heighten interest in the technical possibilities for aluminium in all kinds of electrical equipment, and go far to explain the interest now shown in the properties of aluminium as a conductor material, and of aluminium alloys in both cast and wrought form for machine components.

Standards

Another pointer to a greatly extended use of aluminium is the increasing number of standards now being prepared, largely by the British Standards Institution. Work has begun there on a new series of standards covering "Aluminium for Electrical Purposes," and the first of these, for aluminium wire, is in an advanced stage of preparation: other products contemplated in this series include sections, sheet and strip. At the instigation of the Cable Makers Association a standard is being drafted for "Stranded Aluminium Conductors for Insulated Cables for Electricity Supply," and data are being compiled for the inclusion of aluminium in B.S.1320 "Specification for Overhead Lines on Wooden Poles." The recently revised B.S.480 "Impregnated Paper Insulated Cables for Electricity Supply" lays down requirements for aluminium cable sheathing.

There is also a resurgence of activity in the sub-committee on aluminium of the International Electro-Technical Commission, which is considering international standards of resistivity for aluminium. In Great Britain the value for hard-drawn wire has been fixed at a maximum resistivity of 2·8264 microhm-cm. at 20°C., i.e., 61% of the International Annealed Copper Standard. It marks the improvement in quality of electrical-purity aluminium now supplied, compared with that available when a maximum figure of 2·87 microhm-cm. (60% conductivity) was fixed many years ago in B.S.215. The new value is to be incorporated in all new British Standards involving electrical-purity aluminium wire. The wire used is of a special grade, and although it is nominally at least 99·5% pure aluminium, it is nevertheless specially selected and processed so that the required resistivity value is achieved.

Properties of Aluminium

Table III indicates the properties of copper, lead and 99·5% aluminium as used for cable sheathing, and electrical-purity aluminium as used for conductors. Note the significant differences in the density and weight per cubic foot, in resistivity, and in ultimate tensile strength. Obviously an aluminium conductor has greater bulk than a copper conductor of the same resistance, but it has a considerably lower weight. On the other hand, an aluminium sheath is much stronger than a lead sheath, both as regards tensile strength and fatigue resistance, as well as being several times lighter. The significant factors for a comparison between copper and aluminium when used as conductors are summarised in Table IV.

Aluminium is readily shaped into the forms required for use both as a conductor and as sheathing. In addition to the common forms such as wire, sections for bus-bars and structural purposes, tube for sheathing, strip and sheet, aluminium is readily extruded into complex shapes, and this permits special design of bus-bar sections for optimum electrical characteristics. It is also readily cast, and this is a useful facility for certain conductors, e.g., dead-end assemblies on overhead lines, and pressure die cast rotors for squirrel-cage motors. The easy production of the many types of aluminium alloy die castings used for structural parts, casings, overhead line fittings and accessories, cabinets, etc., is due to the good foundry properties of certain of the alloys.

The following sections review those fields of use in which aluminium conductors are coming into greater prominence, and which represent the main usage of the metal, both now and probably for some time to come.

Overhead Transmission Lines

Plain aluminium and steel-cored-aluminium cables are used all over the world for long distance transmission of power at voltages up to 330 kV. In Great Britain the national grid, erected chiefly in the years 1928 to 1933, was carried out almost entirely in steel-cored-aluminium, and the new "super-grid" operating up to 275 kV is in the same materials. This at present is the largest single use of aluminium as a conductor material. Light weight, good resistance to corrosive attack from the atmosphere, and good conductivity account for the choice of aluminium, coupled with the lower cost compared with other conductor materials.

TABLE III.—PROPERTIES OF METALS USED IN CABLES AND CONDUCTORS

	Copper—High Conductivity Annealed	Lead—Commercial Refined	Al 99·5%—Hot Extruded Tube	Al 99·5%—After Sinking	Al 99·5%—Hard Drawn Wire	Al 99·5%—½H Wire	Al 99·5%—Annealed Wire	Al-0·5% Mg-0·5% Si Specially Heat-Treated
Density at 20° C. (gm./cc.)	8·89	11·37	2·703	2·703	2·703	2·703	2·703	2·70
Weight/cu. ft. (lb.)	555	710	169	169	169	169	169	169
Coefficient of Linear Expansion/° C. × 10⁶	17	29	23	23	23	23	23	23
Melting Point (° C.)	1,083	327	659	659	659	659	659	580–660
Specific Heat (cal./gm.)	0·092	0·031	0·23	0·23	0·23	0·23	0·23	0·23
Thermal Conductivity (cal./cm./sec./° C.)	0·92	0·082	0·54	0·54	0·54	0·54	0·54	0·48
Resistivity at 20° C. (microhm-cm.)	1·724	20·65	2·84	2·84	2·8264	2·8264	2·80	3·22
Temperature Coefficient of Resistance at 20° C.	0·0039	0·0042	0·004	0·004	0·004	0·004	0·004	0·0036
Ultimate Tensile Stress (to nearest ½ in.)	15–16	0·7	4·5–5·5	5·5–7·5	10–12	7–10	4·5–6·5	19·4
Fatigue Endurance Limit (tons/sq. in.) (10^7 reversals)..	±4·5 approx.	±0·18 approx.	±2·5 approx.	±2·8 approx.	±3·8* approx.	±3·8* approx.	±2·2* approx.	—

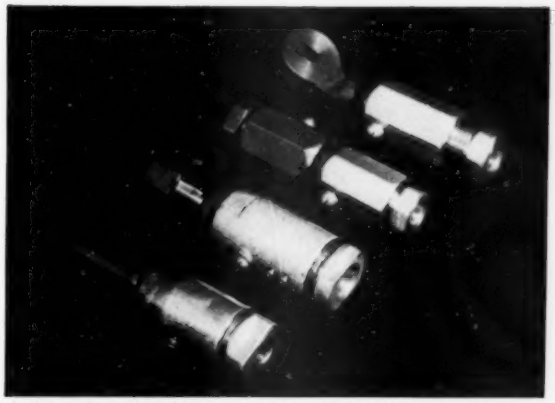
* 5×10^8 reversals

Forrest and Ward[3] recently summarised 20 years' experience with the performance of overhead transmission lines in Britain from the aspect of corrosion: their principal conclusions were that deterioration of S.C.A. conductors varies very greatly according to the environment, being worst in marine and industrial atmospheres. Basing conductor life on a maximum loss of 12% of the mechanical strength of the complete conductor, they estimate that a mean service life of 25 to 30 years may be expected, with a minimum of 10 years or less in heavily industrialised areas, and a life of at least 50 years in many rural areas. When the grid was originally planned a conductor life of 25 years was estimated, but it appears that in most cases a much longer life will be achieved. These findings are in line with those of Champion and Skerry[4] and Herenguel.[5] Forrest and Ward report experiments with the greasing of conductors, which is estimated to add 10 years to their life in industrial atmospheres: experiments are continuing. Hawley, in the discussion of Forrest & Ward's paper, suggested sheathing the stranded aluminium in a solid tubular aluminium sheath, and as it is clear that corrosion of S.C.A. is accelerated in some atmospheres by retention of corrosive agent in the interstices of the strands, this type of construction might justly be expected to improve conductor life. The world-wide use of S.C.A. shows that the results of these corrosion tests in Great Britain are not necessarily a guide to performance elsewhere: thus in hotter, less humid climates, e.g. the Mediterranean area, S.C.A. conductors have a very long life,[5] as is also the case in many parts of the American continent. Moving northwards into colder and more humid climates, it is generally observed that deterioration of transmission lines (as well as of other metallic structures) becomes increasingly rapid, as would be expected.

Aluminium-magnesium-silicon alloy conductors (known as Silmalec in Great Britain and Almalec or Aldrey on the Continent) have been used for many years, particularly in France, because of their greater strength. The properties of this material are indicated in the end column of Table III: it may give better performance than aluminium where galvanic corrosion between steel core wires and the aluminium strands is the predominating factor in the life of the conductor, e.g. in coastal situations.

Recent developments in overhead lines include the manufacture and erection of the largest steel-cored-aluminium cable ever made: 2·295 in. overall diameter, 108/37 strand construction, weighing 4·77 lb./ft., and 3,364,000 circular mils cross section. It conveys power over a 10-mile mountain pass to the great new aluminium reduction plant at Kitimat. For very high voltage lines (above 300 kV) there has recently been put forward in U.S.A. a conductor known as "Expanded A.C.S.R." which consists of steel core wires surrounded by impregnated Kraft paper twine with the aluminium stranding outside. Such a conductor is 15% greater in diameter than normal A.C.S.R. of the same resistance, and is said to reduce considerably corona losses: it is undergoing trials.

There is a good case for aluminium alloy construction of the top hamper of transmission towers: the absence of the need for painting during service eliminates the need for periodic shut-down. Trial top hampers in aluminium alloy H10-WP have been load tested with satisfactory results, and the B.E.A. contemplates erecting a number of towers with aluminium top hamper in order to determine whether the reduced maintenance costs over a period are sufficient to off-set the higher cost of the aluminium construction. Aluminium alloy is also used in the construction of sub-stations for similar reasons—and pure aluminium for the bus-bars.



Fittings for aluminium/copper connections on overhead lines: aluminium and copper alloy sections are screwed together with an insulating material between them.

Aluminium alloy conductor fittings and accessories such as snail clamps are beginning to come into use, their lightness and economy being attractive: hitherto such fittings have been made in malleable iron. Accessories such as dead-end clamps have been cast in pure aluminium for many years.

Overhead Low Voltage Distribution

Plain stranded aluminium conductors for low voltage overhead networks are not yet common in Great Britain, but a sufficient number of schemes have been erected to prove their great promise, both technically and economically. There is little difference in sag between copper and aluminium conductors as used for low tension work, and this means that very little re-designing of the system is needed when changing over to aluminium: the same spans, poles, stays and spacings can still be used, and fewer types of fittings are required. The economic advantages of using aluminium are great, and considerable savings in copper can be achieved. On one erection carried out for trial purposes by the Eastern Electricity Board,[6] a reduction of 30% in the total capital cost of the mains was achieved, and with very little technical difficulty; in fact it was found that although erection was a little slow at first due to the different technique, this was readily mastered and the lighter weight of the aluminium compared with copper was then found to make handling

TABLE IV.—COMPARISON OF ALUMINIUM AND COPPER CONDUCTORS

	Aluminium : Copper
For Equal Resistance	
Area Ratio	1·61 : 1
Diameter Ratio (round conductors)	1·27 : 1
Weight Ratio	0·48 : 1
For Equal Current and Temperature Rise	
Area Ratio	1·39 : 1
Diameter Ratio	1·18 : 1
Weight Ratio	0·42 : 1
For Equal Diameter	
Resistance Ratio	1·61 : 1
Current Carrying Capacity	0·78 : 1

All-aluminium die-cast fitting for aluminium/copper connections. It is squeezed onto the overhead line and the copper tapping is thrust into the smaller hole which is pre-loaded with a special jointing compound : it is then compressed. The massive end section of this part ensures that any corrosion resulting from contact with the copper wire is restricted to the end section which is sufficiently massive to be relatively unaffected.

and erection much easier. Service connections are an important aspect of erection technique : one approach favoured in practice is to carry the aluminium line right to the service cut-out, so that the final connection to tinned brass fittings is made indoors in a dry situation, where the possibility of electrolytic attack of the aluminium is very much less than in an exposed outdoor situation. A further precaution is to apply a long-life grease, such as graphite grease, to the connection to prevent access of moisture. Experience extending to 30 years with joints of aluminium to brass connecting pieces has shown that this technique is satisfactory.

Where a bi-metal connection has to be made in an exposed situation, special bi-metal fittings are used : these are copper or brass terminals connected to an aluminium alloy terminal, the bi-metallic joint being separated by an insulating washer so that all external contact between the dissimilar metals is prevented. Aluminium alloy parallel groove clamps, or split bolt connectors with a plastic shroud filled with grease, are also used. In the United States connectors are designed on the principle of allowing a generous contact area, and making the aluminium compression fitting sufficiently massive to withstand any effects of bi-metallic corrosion that may accrue during the period of service : in addition all bi-metallic connections are coated with a specially prepared grease containing metallic zinc dust.

Compression-type joints are coming into use for low tension lines, the fittings being made of 99·5%-purity aluminium, which is readily compressed, either by small portable hydraulic compressors now available, or by the bolt cropper type of compression tool : the latter provides a cheap and efficient method of making service connections, and may even be used for tension joints, in addition to line taps.[7]

Aluminium H.S.O.S. (house service overhead service) or aluminium P.B.J. cable is not much less in cost than the equivalent size of copper cable—although price fluctuations may change this—but it is advantageous in conjunction with all-aluminium overhead distribution lines as it simplifies the problem of bi-metallic connections. P.V.C. insulated cable is being tested at present as it might offer a saving by continuing the cable right into the cut-out position instead of changing from P.B.J. to H.S.O.S. at the termination of the aerial span.

The whole of this trend towards aluminium for low voltage distribution is of importance in view of the B.E.A. policy of rural electrification, of which the major part is due to be completed by 1958, and the second and final phase by 1963, when it is anticipated that most farms and premises in rural areas will have been provided with an electricity supply.

Insulated Power Cables

The design, manufacture and installation of insulated cables for power distribution is a very complex matter, and the reliability of installations to-day is the result of many years' experience and development. The use of aluminium conductors in place of annealed copper wire is a radical change, but one that is now considered worthy of full technical exploration in view of the substantial ultimate economies to be expected. A number of insulated cables with aluminium cores were installed in various British cities in the early years of the century and gave a very satisfactory performance for periods up to 40 years : both soldered and compression type joints were used and little trouble was encountered with expansion effects. During recent years there has been a revival of interest in aluminium-cored cables, and gradually a body of knowledge based on experience and tests is being built up, so that it will soon be possible—despite the complexities of the matter—to enter into large scale usage of aluminium-cored cables, with aluminium sheaths also. The Cable Makers Association recently issued tables of ratings for aluminium conductors[8] and the B.S.I. is now engaged in preparing a British Standard for stranded aluminium conductors which includes a range of standard sizes. Thus, the foundations are now being laid for the design and use of aluminium-cored insulated cables.

The bulk of an aluminium conductor is normally greater than that of the equivalent copper conductor, the difference depending on whether voltage drop, temperature rise, or current carrying capacity are adopted as criteria. Table IV indicates the important ratios for the two metals. When temperature rise is the criterion, the current rating for aluminium conductor cables is 0·78 that of the same size copper cable up to 0·4 sq. in. cross section, but for larger sizes the ratio may be increased up to 0·83—for example, for a 1·0 sq. in. conductor multi-core cable. The C.M.A. tables of ratings deal with all these aspects of aluminium-cored cables.

But there are other aspects yet to be explored following the advent of the aluminium sheath. It is now possible to make cables with copper conductors or aluminium conductors and with lead sheaths or aluminium sheaths. An aluminium-sheathed, aluminium-cored cable would be little more than half the weight of the conventional lead-sheathed, copper-cored cable of to-day. Such a weight saving is of great advantage in manufacture, transport and installation, to say nothing of the possible saving in first cost. It is becoming clear that the advent of the aluminium sheath has made more feasible and more attractive the use of aluminium for the conductor also, if only because of this great weight saving ; and from the economic aspect also this is the most likely development for the future.

Until recently there was little information about the most appropriate temper of wire to use for the aluminium strand, but it now appears that material of a ¾H temper

is more satisfactory than the fully hard wire normally employed for overhead transmission lines. Wire in the ¾H temper is now available and has a tensile strength of 16–22,000 lb./sq. in. : it passes without difficulty through the stranding machines and is readily amenable to shaping operations for shaped cables. More important, perhaps, it is suited to compression jointing techniques which are now under consideration for the jointing of medium voltage cables above 11 kV : the fully hard wire would not give such good compression joints according to recent American experience.[9] It is worth mentioning that in Europe soft annealed aluminium wire has been used satisfactorily for insulated cables.

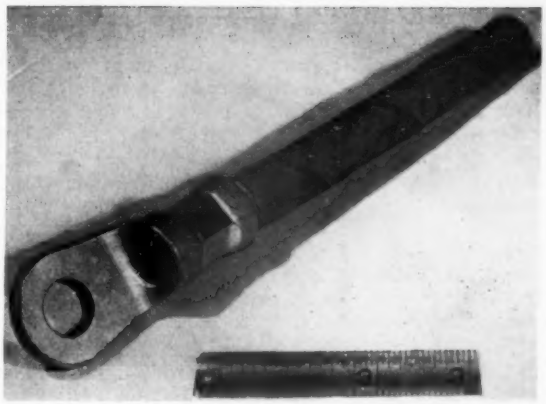
Another technical problem now satisfactorily overcome is the jointing of the stranded conductors. The key to this successful development is undoubtedly the introduction of new types of flux and solder for use with aluminium. Until recently the removal of the stable oxide film on aluminium could not readily be effected by fluxes operating at a reasonable temperature, but organic fluxes based on triethanolamine and incorporating an active fluorine compound have now been developed. It is important to avoid excessive heat, of course, and a solder of appropriate melting point is a lead-base one containing additions of tin, cadmium and zinc, used at a temperature of 310 to 320° C. Tests carried out by cable makers, and confirmed by the B.E.A., have established the reliability and simplicity of the sweating technique now recommended, and which can be employed by jointers after only a very brief training. It is fully described by Ridpath,[10] and is considered satisfactory for jointing cables up to 11kV.

In the U.S.A. manufacturers of jointing equipment and accessories have developed a full range of compression and bolted type connectors for aluminium-aluminium and aluminium-copper joints. Use is made of jointing compounds to improve the stability of the joint, and it is also recommended that the conductor ends should be thoroughly scratch brushed in order to remove the oxide film from the aluminium before making up the connection. Apart from these points there are no significant differences in the jointing techniques for compression joints in aluminium by comparison with copper, and a number of successful installations have been completed.

Plans are being prepared for a number of trial installations of aluminium-cored conductors in various areas. A complete installation of aluminium-cored, aluminium-sheathed cable 0·15 sq. in. section was installed some years ago by the Eastern Electricity Board in the Romford district in lieu of 0·1 sq. in. copper. No great difficulties were encountered in making the installation although the increased stiffness of the aluminium-sheathed cable was noticed. Joints were made by sweating and without difficulty : the jointers received a short course of instruction beforehand.

Fine-Wire Cables

Aluminium is also coming into use for cables made up of finer wires 0·010–0·020 in. diameter. The first development here was probably that of aircraft cables where lightness is of paramount importance. Following war-time developments, there has now been added to the series of rubber insulated Pren cables a series of aluminium-cored cables termed Prenal, for which British Standard E.21 was recently issued " Electric Cables for Aircraft (Glass and Polychloroprene Insulated)."



Courtesy of the Plessey Co., Ltd.

Stamped aluminium terminal lug attached to aluminium stranded Prenal cable by hexagonal crimping. A jointing compound is applied before compressing the lug onto the cable.

Compression joints using a heavy indent or a hexagonal crimp have been perfected, mainly by the Plessey Company, and after full test have been accepted. The pure aluminium lugs used for making joints and terminations are sometimes tin plated to improve contact, although American experimental work suggests that this is not essential. Welding cables of light weight made up with aluminium wires 0·012 in. diameter have also been developed, and this too is a promising application in view of the light weight and the saving in cost that can be achieved in some sizes. Further development work may be needed in respect of the cable construction itself, in order to achieve satisfactory flexing qualities and avoidance of breakage of the strands with prolonged use : these difficulties need not be considered insuperable.

Aluminium Cable Sheathing

Pioneer work in the development of aluminium sheathing for cables was done by Johnson & Phillips, Ltd., in the immediate post-war period when lead was in very short supply and at high price : some experiments on extrusion of aluminium cable sheathing had been done in Germany before the war. In a comprehensive paper before the Institution of Electrical Engineers in 1954, Hollingsworth & Raine[11] describe in detail the characteristics of aluminium as a sheath material, and claim that " Aluminium has been established as a technically suitable and economic sheathing material to replace lead, and that its availability at an economic level constitutes an important asset to the cable industry." It is advantageous because of its light weight, good mechanical strength and freedom from vibration effects : there has been found only one really significant disadvantage, namely the somewhat greater stiffness of the complete cable which, in a few instances, makes installation a little more troublesome. Since 1948, when the aluminium-sheathed cable was first introduced, much experience has been gained and over 2,500 miles of cable have been laid in all types of situation, most of it made by inserting the insulated core into a long extruded aluminium tube and swaging or drawing the tube down on to the core. After early teething troubles a satisfactory technique of manufacture was developed and standardisation of tube sizes and sheath thicknesses has now begun. Some initial trouble was encountered from

corrosion of cables buried underground, but was totally eliminated by the application of P.V.C. tapes under the normal bituminized hessian serving. For many surface installations no protective treatment is needed, other than to ensure that there is not continuous contact under damp conditions with white-washed walls or other structures incorporating alkali building materials. Wiped joints are readily made, the aluminium sheath being initially coated with 90 : 10 tin : zinc solder by a simple technique : thereafter, Grade D and Grade H wiping metals as specified in B.S. 219 : 1932 are satisfactory, the latter being preferable. In many cases the greater strength of the aluminium sheath compared with lead enables wire armouring to be dispensed with.

The full acceptance of aluminium as a sheathing material is exemplified by its incorporation into appropriate British Standards. B.S. 480 issued in revised form in 1954 is now divided into two parts, Part I dealing with lead-sheathed cables and Part II with aluminium-sheathed cables. Aluminium is also used for sheathing rubber insulated cables supplied to B.S. 7, and in this connection its simplicity for installation of control gear and light cables is proving very advantageous. Simple glands, also in aluminium, are available for connecting into standard conduit boxes. Aluminium-sheathed cables have been supplied for use in mines, complying with B.S. 760 : 1943, whilst other installations include those in oil refineries, engineering works, tanneries, refrigeration plants and other environments where corrosion is a factor that has to be considered. Overhead insulated cables supported on catenary wires with aluminium alloy brackets have been erected in rural and desert conditions and in mild industrial atmospheres, light weight being a special advantage here. Following test work with aluminium-sheathed cables in frigates, the Royal Netherlands Navy has adopted this type of cable for cruisers and destroyers, the advantages sought being reduction in weight, increased mechanical strength against accidental damage, resistance to corrosion by marine atmospheres, and complete electrical screening : it is also considered that in the event of fire the higher melting point of aluminium (659° C.) compared with lead (327° C.) is a distinct advantage.

Aluminium sheathed cables attached to aluminium alloy cable trays. The strength of the aluminium sheath greatly simplifies fixing.

Most of the aluminium-sheathed cable supplied in Great Britain has been manufactured by the draw-down method in which the cable core is first threaded through a long extruded aluminium tube and the whole is then passed through a die which draws the sheath down to a snug fit on the cable core. At the same time this increases the strength of the sheath as a result of the cold deformation. Another method developed by Pirelli-General, Ltd., corrugates the sheath. These initial developments have been followed by extensive work in the perfection of special extrusion presses for direct extrusion of the aluminium cable sheath on to the core, and already several presses have been erected for this purpose. British Insulated Callender's Cables have recently installed one such press in which two 3,000-ton diametrically opposed rams operate simultaneously ; it is designed to extrude 99·8% purity aluminium at a temperature of 280° C., low enough to prevent scorching of the insulation. A direct extruded sheath may be expected to be rather less rigid and the cable more easily installed, therefore. On the other hand, sheathing achieved by the draw-down method being stronger is of special value for pressure cables.

Long term creep tests have indicated that under normal working hoop stresses of 2,500 lb./sq. in. the rate of creep at 70° C. for the work-hardened metal is insignificant over an expected life of 35 years.[11] It is considered that there is an adequate margin of safety at working temperatures for cables operating under an internal pressure of 250 lb./sq. in. A number of miles of both oil-filled and gas pressure cables have been installed and tested with satisfactory results, and recently the South East Scotland Electricity Board ordered over 7,000 yds. of 33 kV impregnated pressure cable, 0·25 sq. in. copper section, to be used on a particularly hilly route where this type of cable should obviate any trouble due to compound migration.

A 132 kV aluminium-sheathed oil-filled cable has recently been made for the British Electricity Authority, 0·45 sq. in. copper section, the aluminium sheath being 0·11 in. thick and the overall diameter of the cable 2·81 in., compared with 2·59 in. for a similar cable sheathed in lead. The weight, however, is 16·8 lb./yd., compared with 23·7 lb./yd. for the lead-sheathed cable : the bending radius is similar for both types.

All Aluminium Cable

A logical step from the aluminium-sheathed copper-cored cable is the all-aluminium cable, and here the incentives are reduction in first cost and all the advantages of extreme light weight, particularly with large cables over 0·3 sq. in. equivalent copper section. Hollingsworth and Raine's graphs[11] indicate that a 660-volt 300 kVA cable with copper conductor, lead-sheathed, steel-tape armoured and served, would weigh approximately 215 cwt./1,000 yd. : without steel tape armouring it would be 170 cwt./1,000 yd. : with copper conductor, aluminium-sheathed and served it would weigh 140 cwt./1,000 yd. ; the all-aluminium cable with aluminium conductor, aluminium-sheathed and served would weigh 90 cwt./1,000 yd. Such a substantial reduction in weight may be coupled with a lower capital cost, with the possibility of further considerable economies due to ease of handling the much lighter cable, wider

spacing of supports, and the other indirect reductions in installation costs accruing from lightness alone.

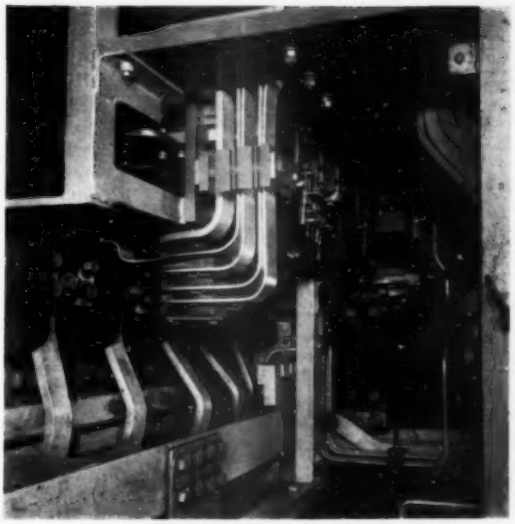
One technical point still requiring investigation is the differential expansion effect with the all-aluminium cable. This would not present a serious problem with multi-core cables, where there is room for adjustment to the thermal stresses, but may be of some significance in single core cables: the matter is now under study experimentally.

Aluminium Alloy Wire Armour

For single core cables, sheath and armour losses due to hysteresis effects can be very great when the normal galvanised steel wire armour is employed, and the use of aluminium with its non-magnetic properties affords a means of reducing such losses considerably. Several installations were made some years ago, mostly for submarine use, and inspection of a submarine cable at Lough Larne, N. Ireland, after 21 years' exposure to sea water indicated that the aluminium alloy armour had not deteriorated. The alloy recommended is an aluminium-2% magnesium alloy, which has high resistance to sea water and marine atmospheres, good strength (15 tons/sq. in. ultimate tensile strength) excellent forming properties, and a good electrical conductivity. The early experience has encouraged the B.E.A. to specify aluminium alloy wire armour for one of the cables in the first trials of the cross channel link between Britain and France. It was estimated that the sheath and armour losses due to circulating currents would be 61% of the conductor loss, compared with a loss of 170% when using galvanised steel wire. Aluminium alloy wire armour is also attractive for trailing cables as used for excavating machinery, or for electrical apparatus in coal mines, where the reduction in weight is beneficial and where the good conductivity of the metal ensures an adequate conductivity for the earth return: in the case of galvanised steel wire armouring this can only be achieved by incorporating copper wires.

Bus-Bars

B.S.159 : 1932 lays down maximum resistivity values for both copper and aluminium bus-bars, the conductivity of the aluminium being taken as 60·6% that of copper. An aluminium bar of equal resistance, therefore, has a cross-sectional area 1·6 times that of a copper bar, but its weight is only half. The larger cross section of the aluminium is of advantage from the point of view of heat dissipation, particularly if the bars are blackened. Furthermore, when heavy alternating currents are being transmitted the "skin" effect is considerably reduced: thus in the case of flat bar it does not manifest itself to any serious extent up to $\frac{1}{2}$ in. thickness, whereas $\frac{3}{8}$ in. is generally considered the upper limit of thickness for copper bar. The main attraction for aluminium as a bus-bar material, however, is the great reduction in cost that can be achieved, and many cases are quoted, in France and the U.S.A. particularly, where the use of aluminium has reduced the capital cost by 50%. This, of course, is particularly applicable where large bus-bars carrying heavy currents, are involved, and a lesser figure would be expected with small bus-bars as used in many types of switch-gear and control gear, although here the saving in costs is still of a very attractive order. The G.P.O. has recently standardised on aluminium as a bus-bar material for stations and exchanges.



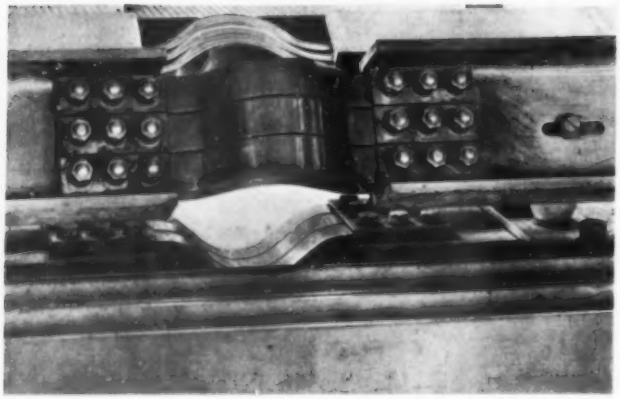
Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

Aluminium bus-bars in the British experimental gas turbine locomotive "18100."

Aluminium bus-bars are supplied in a wide range of sizes up to 15 in. in width and down to a minimum of $\frac{1}{16}$ in. thickness. The ease of extrusion of aluminium also makes it possible to obtain special shapes of bar, for optimum electrical conditions. A recent heavy bus-bar installation at the G.E.C. works at Witton [12] makes use of three channels in triangular formation for carrying a maximum of 5,000 amps. at 880 volts A.C., the channels being 8 × 3½ in. extrusions, as illustrated. These bars were erected overhead, this being facilitated by the lighter weight of the aluminium. It should be possible to extend this adaptation of the extrusion process to bus-bar design for special requirements, e.g., the provision of cooling fins and the provision of special shapes for particular installations. An example of a rising main in an American building indicates the potentialities of this approach.

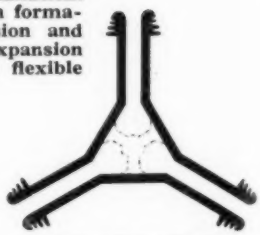
For bus-bar connections in switchgear, aluminium has not been much favoured until recently, possibly due to some lingering uncertainty about the stability of bolted connections. A review of experience with bolted connections used for over 25 years indicates, however, that very stable joints can be achieved provided due attention is given to the design of the joint, taking into account the lower strength of aluminium compared with copper. B.S.159 recommends vigorous scratch brushing of the contacting surfaces under a neutral petroleum jelly, and experience has borne out that this method, or draw-filing, is a satisfactory way of removing the oxide film prior to bolting up. Bolts of generous size are recommended, in order to develop the necessary pressure between the bars, particularly at stud joints where the contact area may not always be as great as desired. Clamping is also a very good method. Recent comparisons between the jointing of aluminium bus-bars and copper bus-bars of small size [13] indicate that the above recommendations are sound, and that aluminium and copper are equally responsive to good jointing techniques, and both may suffer from inferior methods.

There is at present considerable interest in alternative methods of surface preparation, e.g., silver plating or



Courtesy of G.E.C. Engineering Works, Witton

Left—8 × 3½ in. channel aluminium bus-bars in a heavy installation. The bars are arranged in formation for A.C. transmission and incorporate camel-back expansion joints consisting of nine flexible strips.



Courtesy of Electrical Engineering

Right—Three-phase A.C. bus-bar 12½ in. wide × ⅛ in. thick, closely spaced for minimum reactance. The fins increase longitudinal rigidity and assist heat dissipation.

smearing the contacting surfaces with special compounds containing hard particles, metal powders, or active chemicals that dissolve the oxide film. Sufficient data are not at present available regarding these new techniques to enable useful comment to be made : the use of Belleville or cup washers to accommodate thermal stresses has also been advocated, and many joints have been made on large bus-bar installations using such washers, particularly in France. It has not been definitely established, however, that they are necessary, and any possibility of relaxation of the joint due to differential expansion of the steel bolts compared with the aluminium bar could be eliminated by the use of aluminium alloy bolts of sufficiently large size to develop the necessary clamping stress.

A new development in small size bus-bars for switchgear work originating in the U.S.A. is an aluminium alloy bus-bar which is considerably stronger than the pure aluminium normally specified : it has a tensile strength of 13 tons/sq. in. and a conductivity 55% that of copper. Such a bar would undoubtedly be advantageous as its increased strength and hardness may be expected to improve the stability of small bolted connections and also reduce the effects of short-circuit stresses.

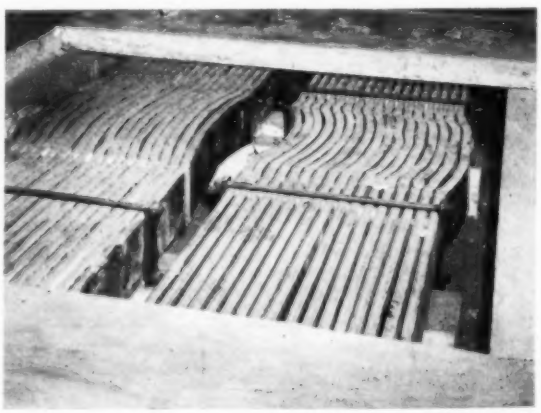
Other successful methods of jointing are welding and brazing. The argon-arc welding process enables a considerable measure of pre-fabrication of permanent bus-bar installations to be made, thus greatly easing erection problems : the joints are of low resistance and quite stable under thermal and corrosive conditions. Brazing has been adopted, where preferred, and is equally successful provided the corrosive brazing flux is entirely removed afterwards.

There is increasing interest in the possibilities of aluminium bus-bars for transport vehicles such as underground trains and diesel-electric locomotives, and two installations in diesel-electric locomotives have recently been described.[14] The use of aluminium bus-bars and cable on a standard American 1,600 h.p. diesel-electric locomotive reduced the weight by 500 lb. and also diminished the first cost of the installation. Heavy duty aluminium bus-bars are also used on the experimental British Railways gas turbine locomotive for similar reasons,[15] and incorporate welded joints.

Telecommunications

Economic advantage and technical efficiency have both stimulated the use of aluminium for radio, radar, television and high frequency equipment, as well as in normal telephone apparatus. Many hundreds of miles of high frequency co-oxial cable with central copper conductor and aluminium sheath have been produced, this development being favoured by the ease with which aluminium tubing can be extruded, the lightness, good conductivity for the return circuit, and resistance to atmospheric attack. Much of this type of apparatus is located high above the ground and the light weight facilitates erection and eases the problem of support. For similar reasons T.V. antennae and parabolic reflectors for cross-country T.V. links are fabricated in aluminium. More familiar uses in radio sets are the condensers made from aluminium foil, screening effected with impact extrusions in aluminium, and chassis and cabinets made from fabricated sheet or from die castings in aluminium alloy. Much radar and radio equipment needs to be portable, and the light weight and sturdiness of aluminium cabinets are desirable features. Considerable lengths of aluminium-sheathed cable are employed for re-diffusion of radio and T.V. programmes in suburban areas.

Aluminium is coming into use, both for the conductors and the sheathing of underground telephone cables. Bell Telephone Co., U.S.A., have increasingly adopted



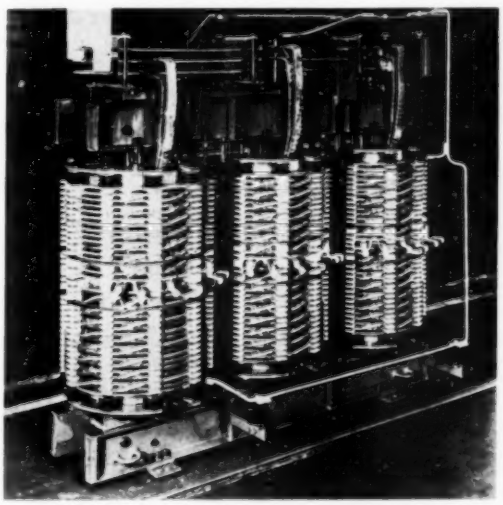
Courtesy of Life Time Syndicate, U.S.A.

Welded joints in heavy bus-bar installation in an aluminium reduction plant. The joints are made by self-adjusting consumable electrode welding in 10 × 1½ in. bars bevelled at the joint to facilitate welding. Expansion joints consisting of flexible strips in a pack are readily jointed by welding.

aluminium, and have developed composite sheathing processes involving aluminium strip coupled with steel or with plastics that reduce the first cost of the cable itself.[16] This in turn has increased the possibility of using aluminium for the conductors, as the increase in bulk that this necessitates by comparison with copper has proportionately less effect on the increased cost of the sheath, the latter being made more cheaply than hitherto.

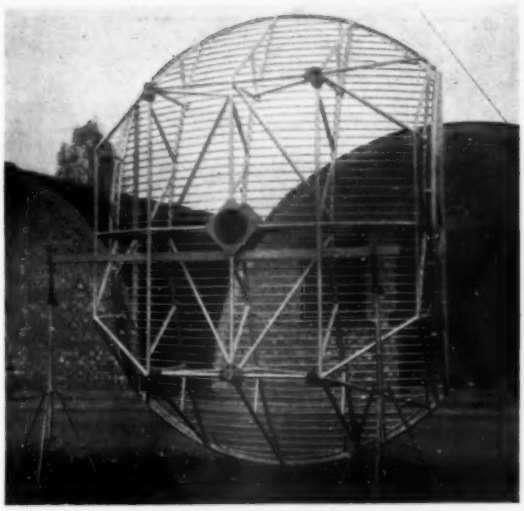
Considerable progress has occurred in the development of jointing techniques for single aluminium wires as used in telephone work and in windings for many purposes. The G.E.C. in England have developed techniques and tools for the cold welding of aluminium, either by butt welding or by welding two wires laid side by side. Cold welding is now permitted in a number of important items, such as aluminium for overhead transmission lines when joints are made in the early stages of manufacture. Another simple and effective method is to twist the two wire ends together and arc the tip on a carbon electrode connected to an ordinary car battery; this fuses the wire ends together to form a bead giving a reliable welded connection, and is both quick and effective. Alternatively, the wire ends may be fused together with a small oxy-acetylene flame, a small quantity of non-corrosive flux being applied to facilitate agglomeration of the molten bead. For connections to terminal posts a new technique developed by Bell Telephone Laboratories for general telephone work is applicable to aluminium as well as to copper.[17] This consists of wrapping the wire under tension around a square or rectangular terminal post with the aid of a simple tool. It has been established that a solderless wrapped connection of this type, made with about 4 turns, remains intact under thermal cycling and is not prone to relaxation. It is a very simple, quick, and effective way.

It is obvious from these developments that the problem of jointing aluminium wires, which was held to be a deterrent in the past, is no longer an obstacle. It is not surprising therefore, that installations are now being made of underground multiple telephone cables with aluminium conductors. These pilot trials will serve to consolidate techniques for a wider use of aluminium conductors in the future.



Courtesy of Westinghouse Corporation, U.S.A

Aluminium windings and bus structure in a 500 kVA 2,400/480 V dry-type power transformer.

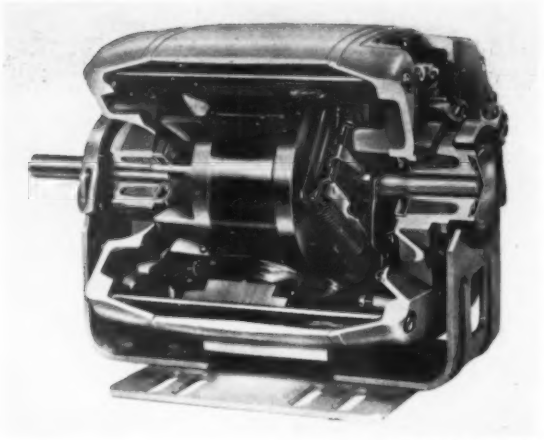


Rear view of one of the parabolic reflectors used in the TV radio link between Birmingham and London. The reflector consists of aluminium alloy tubing and castings assembled by welding and bolting; total weight 450 lb.

Windings

As early as 1919, aluminium strip was used for windings of large alternators in France[18]; these were relatively slow machines, 750 r.p.m., and the full advantages of light weight in reducing centrifugal forces were not exploited. A recent American experiment makes use of a special alloy of aluminium named Condal, developed by the General Electric Company of America. This material has 59% conductivity (I.A.C.S.) and a very much higher creep resistance than normal electrical-purity aluminium, and is, therefore, able to resist the high centrifugal forces involved in 3,600 r.p.m. turbo-generators. A number of 216,000 kVA generators operating at 30 lb. hydrogen pressure have been equipped with Condal field and rotor windings, and at least 18 machines have been wound in this way since 1949.[19] Possibly these are exceptional machines, but the success of the application is significant for the future, should the trend to ever larger generators continue. In the U.K., the speed and size of alternators is not so great as in the U.S.A., and the immediate application of an aluminium alloy for windings is not so obvious; nevertheless there may be other uses for Condal, or its British equivalent, e.g., in salient pole machines, and plans have been made to make this material available in Britain.

More common perhaps is the use of aluminium for the windings of transformers, particularly the dry types where the relatively large insulation clearances causes less difficulty due to the larger conductor sizes required when using aluminium. Leading equipment manufacturers in Great Britain are conducting a number of tests with aluminium-wound transformers. Aluminium has been used also for the tanks of very large transformers, due to the lower overall weight thus achieved, which greatly facilitates transportation from the manufacturers' works. The incentive to use aluminium for windings of large machines is largely an economic one,



Courtesy of Hoover, Ltd.

Light weight fractional horse power motor with die cast aluminium alloy housing and pressure die cast pure aluminium rotor.

although weight saving is also an important aspect. In the case of oil-filled transformers, aluminium may possibly cause less deterioration of the oil, as it does not promote undesirable catalytic action and reduces sludge formation. Furthermore, the development of anodically-oxidised aluminium windings would improve the space factor and also the cooling rate of the windings in the oil bath, an advantage under overload conditions. Large aluminium-wound transformers of 20,000 and 10,000 kVA capacity have been manufactured in Canada and Switzerland, and have been in satisfactory operation for over 6 years, comparing favourably as regards their efficiency and regulation with copper-wound transformers.[19]

For the windings of smaller machines such as electric motors, aluminium wire can be insulated with enamel such as Formvar or Bicalex. The space factor has presented a problem due to the lower conductivity of aluminium, but this can be overcome either by precision winding or by increasing the number of laminations in the stack. The latter expedient was adopted by the General Electric Company in America in winding many thousands of small motors for washing machines, and these installations have given no trouble.[20] Similar jointing techniques to those mentioned above for single wires in telephone work have been adopted, as well as a simple compression joint involving an aluminium tubular sleeve slipped over the joint and compressed with a small hand-operated tool. This serves for copper-aluminium connections also. British electric motor manufacturers have conducted experiments with aluminium windings, for motors of various sizes, and there is scope for the development of insulated aluminium wire as a regular product. Only thus can its use be stimulated. Anodically-insulated wire is regularly used for coils and other items in electronic apparatus—television cameras, for example—and the continuous anodising of wire has been developed in Great Britain to the point of being a routine production process for large scale supply. Such wire can be used at considerably higher temperatures than wire treated with organic insulation or enamel, and this may lead to its application in special apparatus where a high temperature must be tolerated. Experiments are being made with insulation by means of the newer plastics such as nylon and Isoperlon, which can sometimes be applied to wires in very thin sheaths, extruded around the wire by a continuous process.[21]

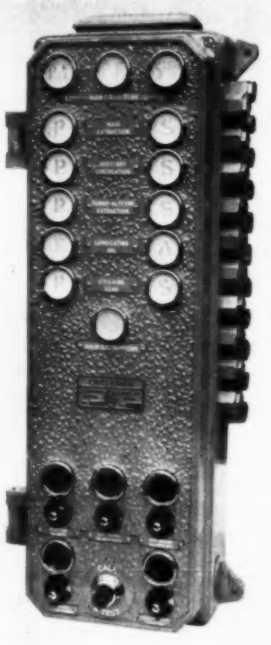
Miscellaneous Uses

In addition to its use as a conductor material in electrical machinery, aluminium finds wide use in the form of wrought and cast products for many pieces of equipment. Casings for metal-clad switchgear, reciprocating parts in control gear, meter cases, bus-bar fittings, overhead conductor accessories, radar cabinets and screens, motor housings and similar items, domestic appliances, and lighting fittings are among the manifold uses of this nature. Fractional horse power motors are now made with aluminium alloy housings cast around the field laminations: the rotors incorporate pressure die cast pure aluminium windings with integral fan, and the end casings are also produced as die castings. In this way, a very light motor is achieved at a low production cost.[22]

Conclusion

This review witnesses to the great interest now being taken in aluminium as a conductor material, and indicates a general trend to the adoption of aluminium for both conductors and other components in electrical machinery of all types.

In certain applications, for example transmission at very high voltage, the technical merits of aluminium are the important considerations: light weight is advantageous in very large heavy machines and in transport. But in all cases the main attraction is an economic one: aluminium offers a real chance of reducing first costs, and is not limited in supply. The possibility of a shortage in the established conductor material, copper, can never be entirely dismissed, and its continued high price, despite the freeing of the copper market, is a further incentive. The position in respect of lead and zinc is similar in several respects, although less pronounced.



Courtesy of Clifford and Snell, Ltd.

Cast LM-4aluminium alloy case and cover for switchgear, 36 × 12 in.

As in many other cases where economic considerations dictate the adoption of a new material, the technical difficulties are being tackled vigorously, and usually with success. One of the chief difficulties associated with aluminium has been that of effecting good joints by simple practical techniques : the stage has already been reached where jointing no longer presents a real problem, whether it be the jointing of stranded insulated conductors, single wires, bus-bars or switchgear.

A considerable body of experience in the application of aluminium is now being acquired, and standards covering the various uses are being prepared, even though aluminium is not at present employed on such a wide scale as may certainly be expected in the future. A continuation of the present economic situation in respect of copper, zinc and lead—and there is no reason to suppose that any great change will occur in the foreseeable future—may well cause the present rapid increase in the use of aluminium in electrical apparatus to become a major change-over.

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Courtesy of Oerlikon Engineering Co., Zurich.

Lightning arrestor for 180 kV 10,000 amp. discharge current, incorporating aluminium castings.

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Ultrasonic Cleaning Plant

AN ultrasonic cleaning plant which is the first of its kind to be made in Europe, and believed to be the first completely automatic unit in the world, has been made to the order of a well-known firm who require to clean small precision engineering parts to a degree not obtainable with conventional cleaning equipment. The firms responsible for its production are Ultrasonics, Ltd., and Mullard, Ltd., who were approached by the Board of Trade, when the customer wished to import a machine from the U.S.A., to see if a unit could be produced in this country. As no information was available as to the type of plant produced in the U.S., this unit had to be designed and produced from scratch in two months due to the urgency of the user's requirements.

It has been established that if an article to which foreign particles, e.g., grease or other matter is adhering, is irradiated ultrasonically in a bath containing a suitable fluid, the part will be made chemically clean. The ultrasonic energy is able to reach those parts of the articles which are normally inaccessible, and foreign particles are rapidly dislodged. A suitable frequency and intensity are necessary, depending on the nature of the material to be cleaned. In this particular plant the frequency is 1 Mc/sec., and the maximum intensity at the transducers approximately 5 watts/sq. cm. This means that the generator, which has an output capacity of 2½ kW., is sending out electrical pulses at the rate of one million per second. The barium titanate transducers vibrate in sympathy with the frequency of the generator, and the energy is transferred from the transducers directly into the liquid. Barium titanate is a man-made ceramic crystal which has the advantage over quartz of needing

only low voltages for excitation, and which can, therefore, be operated in direct contact with the liquid.

The parts to be cleaned are placed in open wire mesh trays. These run into the plant on rollers and are automatically backed up on a conveyor which takes them through the two stage cleaning process. The cleaning fluid is recirculated through a magnetic filter in the first stage, and a combination of magnetic and ceramic filters in the second stage. At the end of the conveyor system the trays are transferred to another roller conveyor on which they travel to the next stage in production. It is estimated that over one million parts will be cleaned daily in this machine. The variable speed drive on the conveyor allows considerable latitude, so that the plant can be run at a speed to match the production rate of the preceding processes. The cleaning fluid in the tanks can be removed simply by the operation of valves, and a new charge introduced. The old fluid can be delivered by the pumps on the plant to distillation equipment, where it is prepared for further use.

Resistance Welding Demonstration Room

FACED with the need for high outputs, production engineers in many industries are turning to resistance welding to provide an answer to their problems. Spot and seam welding can frequently be the means of giving outputs quite unattainable by other methods of joining metals. The choice of machine however can present difficulties. Inherent in the process of resistance welding are a number of variable factors, such as heat control, electrode pressure, timing and arm length, which render a simple statement of size of machine for a particular job very difficult; moreover, the output required and the quality of the joint have an important bearing on the machine to be chosen. Added to this, many engineers prefer to see the assembly welded before finalising their manufacturing procedure. For all these reasons it is becoming increasingly important to be able to weld up samples at short notice.

In order to do this without interfering with normal production of machines, and in an atmosphere remote from the noise of a workshop, Siemens-Schuckert (Great Britain), Ltd., operates a fully equipped special Resistance Welding Demonstration Room in their factory on the Great West Road. It occupies a space of 62 × 21 ft. and is equipped with a large number of different sizes and types of machines. These cover the whole range from the spot welding of the finest gauge of wire, such as used for small valve filaments, to the seam welding of large pressure-tight drums. Pedal-operated and air-operated machines are installed, and the two methods of current control of seam welders, by modulator and by ignitron panels, are in use.

As will be seen from the illustration, the machines are ranged along one side of the room in order of size, and the current, water and compressed air supplies have been arranged very neatly so as not to interfere with the demonstration of welding on any particular machine. The features of each machine can be fully examined. The visitor can see the welding of his own or typical samples carried out on various machines successively, and can compare results in order to determine the choice of the most suitable size of machine, in relation to his particular output requirements.

The Demonstration Room also contains a variety of the other products of this Company, and includes a number of electric furnaces for heat treatment at temperatures up to 1,400° C., and a low tension distribution switchboard which controls a number of the machines in the room; the feature of this board is that while outwardly it is no larger than the conventional switch fuse distribution board, each circuit is in fact equipped with an automatic circuit breaker with current balance earth leakage protection—a feature which is being found indispensible from the aspect of safety in factories, and which is recommended for adoption in the 1952 Report of " Electrical Accidents and their Causes."

At one end of the Demonstration Room and separated from it by a partition, is a small workroom where work incidental to the welding of samples, and the preparation of prototype parts, can be carried out.

Electrolytic Cobalt Production in Canada

As a result of improvements in refining techniques, The International Nickel Company of Canada, Ltd., has initiated production of electrolytic cobalt at its Port Colborne refinery. This is the first commercial production of electrolytic cobalt in Canada. Heretofore Inco's entire cobalt output has been marketed as oxides and salts produced at its Clydach Refinery in S. Wales. Through its new process the company makes available a high purity cobalt which is a fitting companion to its electrolytic nickel. This electrolytic cobalt will be particularly valuable in the manufacture of alloys where high purity is advantageous. Inco's electrolytic process for the production of cobalt was developed after extensive research and pilot plant studies by the company.

Cobalt is one of 13 elements recovered from the company's Sudbury District, Ontario, ores. Nickel, of course, is the principal product. The others are copper, platinum, palladium, ruthenium, iridium, rhodium, gold, silver, selenium and tellurium. In addition, Inco furnishes high quality smelter gas for conversion into liquid sulphur dioxide and normal smelter gas for sulphuric acid production. Soon, iron will be recovered as premium grade iron ore.

Zinc and its Uses: 1952-54

Specially contributed by the Staff of the Zinc Development Association

The European sheet galvanising industry is developing a pattern similar to that of the industry in the U.S.A., whilst the pressure die casting industry in Europe is making great strides in international co-operation. Other important developments concern the use of zinc oxide in rubber, "zinc-rich" paints, improved zinc compositions for cathodic protection, and tin-zinc plated coatings.

Zinc Production

THE period covered by this review has been marked by great changes in the balance between the supply of and the demand for zinc. Many factors have been at work, such as the reopening of the London free market and the natural tendency of the zinc-consuming industries to advance—a tendency which has been particularly notable in Europe during the period under review. So, at the beginning of 1952, partly as the result of American stock-piling, supplies were still short, although less acutely so than in the previous two years. During 1952 the situation improved considerably, and in January, 1953, trading in zinc was resumed on the London Metal Exchange after almost 14 years of state trading by the British Government. At first the British price fell from £110 to £95 per long ton, and continued to fall until April, 1953 when it was about £65 per ton. Since then it has slowly risen and at the end of 1954 was almost £84 per ton. In spite of the lower prices since 1953, world mine and smelter production (see Table I) has continued to grow, and in 1954 was at the highest level on record.

Consumption has also risen and the figures for 1954 were the highest ever. The details are given in Table I, which shows that since the war production has been in excess of consumption; the surplus production has been largely taken up by the U.S. stock-pile, which is thought to have absorbed some 10% of the world's production in most years since the war.

The figures in Table I, which show that both world production and consumption are expanding, hide the fact that recently this expansion has not taken place in all countries, but mainly in Europe, and that in 1953–54 there has been some decline in the United States. In Europe and European overseas territories, mine and smelter production (Table II) and consumption (Table III) have been at record levels since the beginning of 1953, while in the United States mine production in 1953 and 1954 has been much lower than in previous years, the lower prices having forced some high cost mines to curtail their production or to close altogether. The imports of concentrates into the U.S. were increased, and smelter production in 1953 was at the highest post-war level, although it fell off in 1954. Consumption in 1953 (Table III) was also at the highest post-war level but fell sharply in 1954, although it did recover to a good level by the end of the year. The decline in the output of zinc from American mines has led to an extension of the American stock-piling programme for lead and zinc of domestic origin, in order to maintain the American sources which would be invaluable in time of war, and this has already begun to lower the high level of stock held by American producers in 1953 and at the beginning of 1954.

Included in the figures for European production are the outputs of the new electrolytic refinery in the Belgian Congo, which began operating in 1953 when 8,000 tons of zinc were produced: its annual capacity will be about 40,000 tons. European production was also expanded in 1953–54 by the installation of some vertical retort units in France.

A feature of recent years has been the discovery of important new ore bodies, mainly in Canada; but these are not likely to be exploited for some time yet, unless indeed exploitation is justified by the need for supplies of the other metals found in association with zinc. In any case, these new discoveries are reassuring and should dispel any fears that the supply of zinc may be exhausted in the foreseeable future.

TABLE I.—FREE WORLD PRODUCTION AND CONSUMPTION OF ZINC.

(000 of metric tons)

	1935–38 (yearly average)	1950	1951	1952	1953	1954 (estimated)
Mine Production (recoverable zinc content)	1627	1960	2080	2229	2248	2250
Metal Production..	1357	1833	1915	1977	2056	2060
Metal Consumption	1354	1814	1814	1694	1850	1925

TABLE II.—ZINC PRODUCTION.

(*a*) Mine Production (recoverable zinc content). (000 of metric tons)

	1935–39 (yearly average)	1950	1951	1952	1953	1954 (estimated)
Europe and Overseas Territories ..	278	375	429	462	492	560
U.S.A.	493	566	618	604	485	434
Remainder of World (excluding U.S.S.R. and Satellites)	856	1019	1033	1163	1271	1256
Total	1627	1960	2080	2229	2248	2250

(*b*) Primary Zinc Production. (000 of metric tons)

	1935–39 (yearly average)	1950	1951	1952	1953	1954 (estimated)
Europe and Overseas Territories ..	546	604	646	633	663	777
U.S.A.	452	826	844	871	881	788
Remainder of World (excluding U.S.S.R. and Satellites)	359	403	425	473	512	495
Total	1357	1833	1915	1977	2056	2060

TABLE III.—ZINC CONSUMPTION.
(000 of metric tons)

	1935–38 (yearly average)	1950	1951	1952	1953	1954 (estimated)
Europe and Overseas Territories ..	663	715	704	616	648	838
U.S.A.	467	877	847	774	887	761
Remainder of World (excluding U.S.S.R. and Satellites)	224	222	263	304	315	326
Total	1354	1814	1814	1694	1850	1925

Extraction Processes

While no revolutionary changes have been reported in the major zinc extraction processes, a considerable amount of effort has been devoted in various parts of the world to improvements in the operations involved. In the U.S.A. a large sintering machine has been built[1] with strand dimensions of 12 ft. × 168 ft.; this has a capacity of 600 tons of zinc concentrates per day, and is probably the largest single sulphide ore roasting unit ever built. Another American development in the field of thermal extraction is the Sterling process, which has been brought to the stage of commercial application.[2,3] Here the intense heat of the electric arc furnace is utilised in smelting a range of feeds from crude ore to high-grade zinc concentrates.

Work in Germany has mainly been concerned with the treatment of residues or low-grade complex ores in revolving furnaces.[4,5] The Waelz process, which was developed in Germany in the 1920's, and uses a rotating kiln to concentrate zinc-bearing residues, has recently been put into operation in Britain at Avonmouth.[6]

A novel process for the electrolytic extraction of both copper and zinc from a single electrolyte, following fluidised roasting of the ore, has been established in Japan,[7] and a new electrolyti cplant in Italy[8] pro duces zinc from calamine ores, particularly those containing 12–14% Zn, which are concentrated by flotation from previously discarded tailings.

Consumption

In 1952 the consumption of zinc in Europe was at the lowest level since the war, perhaps because consumers of zinc goods were using up stocks which they had built up during periods of shortage in previous years. By 1953, however, there was some improvement, followed by a very sharp rise in 1954, when all the main uses of zinc were at their highest post-war levels. In the U.S.A., on the other hand, although all uses of zinc showed increases in 1953, the trade recession during the middle of 1954 curtailed them to some extent, brass-making suffering more than the others. There was, however, a great all-round improvement towards the end of 1954 with excellent prospects for 1955.

Hot dip galvanising in Europe accounted for 300,000 tons of zinc in 1953, an increase of 10% over 1952. The biggest increase was in sheet and strip galvanising, now the largest branch of the industry, which used 33% of the galvanising total; finished product galvanising took about 30%, and wire and tube galvanising together accounted for the remaining 37%. The amount of zinc used for sheet and strip galvanising in Europe, however, is still below the pre-war level, mainly as a result of the decline in exports to countries in Africa, Asia and South America, where local industries have been established or expanded. After allowance for this factor, the European figures reflect the increased consciousness throughout the world of the value of galvanising for protecting steelwork. The American figures show the same trend: consumption for galvanising was 370,000 tons in 1953, and the estimated figure for 1954 of 358,000 tons shows the smallest decline (3·2%) in consumption for any use of zinc in the U.S.A.

The total consumption of zinc for die casting in Europe was about 60,000 tons in 1953, compared with 50,000 tons in 1952; nearly half of this was used in Britain, where, during the last four months of 1953, consumption reached an annual rate of 38,000 tons—the highest since the war; there has been a further improvement in 1954. The delay between the fall in price and this increase in zinc use is probably due to the time lag between ordering new dies and putting them into production. In the U.S.A., consumption for die casting reached 279,000 tons in 1953 compared with 216,000 tons in 1952, and is estimated at 240,000 tons for 1954.

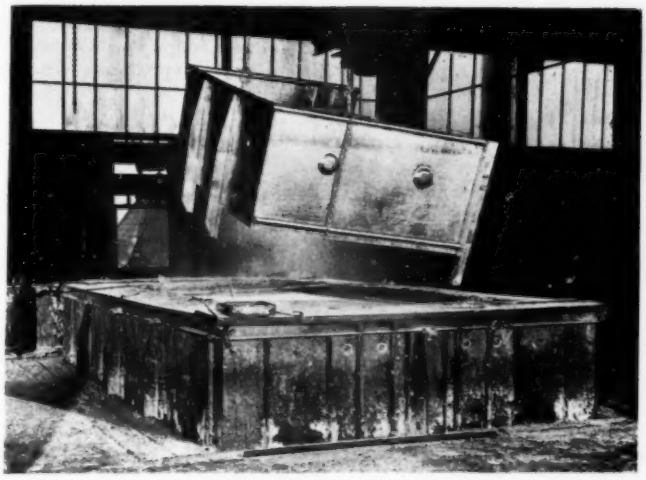
The use of primary zinc for brass production has been maintained in Europe during 1954 at the high level of post-war years, after a decline during 1953, probably attributable to buyers anticipating a fall in the price of copper prior to the resumption of dealings on the London Metal Exchange; the European usage of zinc for brass was 85,000 tons in 1953, of which one-half was used in Britain. The use of zinc for brass production in the U.S.A. rose to 162,000 tons in 1953, but is expected to show a fall of some 40% from this figure in 1954. Brass-making is, however, a far less important use of zinc in the U.S. than elsewhere, only 12% of the primary zinc being used for this purpose. Brass in the U.S. has been to a large extent displaced by newer materials such as die cast zinc alloy.

The demand for zinc oxide in Europe remains at a steady level, rubber manufacture now being its major use in some countries in view of the competition from titanium dioxide in the field of paint pigments. In the U.S.A. the 1954 consumption of zinc oxide is expected to be approximately the same as the 1952 figure of 15,000 tons.

The use of rolled zinc in sheet and strip continues to be one of the main outlets for the metal in France, Belgium, and, to a lesser extent, in Germany, where zinc roofs, gutters and rain-water pipes are widely employed. Rolled zinc is being used for new buildings as well as for repairing old roofs, and there seem to be good reasons for supposing that its present level of consumption on the Continent will be maintained. In both the U.K. and the U.S.A., rolled zinc remains a less important use, accounting for some 10% only of the total zinc consumption. Zinc shows no signs of losing ground to other building materials, and increased interest in the metal has recently been shown by architects and builders in the U.K.

Hot Dip Galvanising

The galvanising industry has recovered well from the difficulties which it experienced after the war, when modernisation of plant was limited by shortage of equipment and building restrictions, and again later on when zinc was scarce. In particular, the plants specially laid down for galvanising windows in Britain have given a good lead to general galvanising, and have set a standard of efficiency for this specialist application unrivalled anywhere in the world.



Galvanising large articles.

Fig. 1.—(Left.)—A half-body of a 13-ton general purpose wagon for British Railways. This formed part of a batch of wagons galvanised experimentally during 1954.

Fig. 2.—(Right.)—An intake screen for a hydro-electric scheme in New Zealand.

In the galvanised sheet industry, the outstanding development in recent years has been the great increase in the number of continuous strip galvanising plants; in the U.S.A. there are now 27 lines either operating or under construction. Many of these use the well-known Sendzimir system or are closely allied to it in principle, employing a heat treatment in a hydrogen atmosphere as a substitute for pickling and fluxing. The recently introduced Cook-Norteman process[9] differs from these, however, in that annealing is not performed "in the line." Fluxes are used, and the control of coating quality depends on the very uniform mixing of zinc and aluminium in the bath achieved by electrical induction heating.

The continuous galvanising of strip is, of course, the logical sequence to the process for its continuous production, and in the U.K. there are now three Sendzimir type units operating and a fourth being laid down. In Europe large quantities of steel strip have only recently begun to flow from the new steel plants, many of which have been built with Marshall Aid funds. These plants constitute an important step towards the integration of the European steel industry, and their outputs will not be limited by local or even national demands. As a result many new new strip galvanising plants are appearing in Europe. In France two units are operating, two are under construction, and one is in the planning stage, while other lines are being built in Italy and Belgium.

The rapid increase in the production of galvanised strip will have its impact on general galvanising, and it is expected that some articles previously galvanised after fabrication will in future be made from galvanised strip. An example of this trend is the plant recently opened in the U.S. for manufacturing steel window frames from galvanised strip. The possibilities of manufacturing hollow-ware from such strip are being widely explored and a further promising outlet for the strip is for non-returnable containers.

Developments in the galvanising industry in Britain and Europe are to be viewed against the background of its size, which is of the same order as that of the U.S. industry. For geographical and national reasons, however, the industry in the U.K. and Europe has not in the past been so closely integrated as is the case in the U.S.A., and has suffered somewhat in comparison. These points are clearly made in the report of European Technical Assistance Mission No. 78, published by the O.E.E.C.[10] The Mission's visit was made to the U.S.A. in 1951 with wider terms of reference than the previous British Productivity Team,[11, 12] being concerned with the specialist galvanising of sheet and strip, wire and wire products, and tubes, as well as the galvanising of finished products. The report shows that, while the best European practice is in no way inferior to that in the U.S.A., galvanising in Europe has so far suffered from its sub-division into a series of national industries with limited markets. In the U.S. the huge integrated market for galvanised goods has allowed a degree of standardisation and specialisation unknown in Europe.

The report finds that in all branches of the American industry, high productivity is achieved as the result of high throughputs, continuous working of plant, good mechanical handling schemes, a marked degree of standardisation of products, the avoidance of unnecessarily high standards of finish, and the progressive outlook of American labour. The more widespread use of galvanised sheet in the U.S.A., including continuously galvanised strip, enables building materials, hollow-ware, agricultural troughs, and other products to be made more economically than by the older batch-type processes or those involving galvanising after fabrication. The tube galvanising industry shows little difference from that in Europe, except for the greater output of galvanised conduit piping. In general galvanising, the almost universal use of sulphuric acid instead of hydrochloric acid for pickling shows advantages of cheapness, ready transportability, and a wider choice of construction

materials for pickling equipment in high-production plants; in Europe, however, the cost of heating militates against the use of sulphuric acid, except for vats of consistently high throughput.

Following this Mission, further efforts were made to increase technical co-operation in the European industry, in which the Zinc Development Association and the affiliated Hot Dip Galvanisers Association continued to play an important part, mainly through the organising of international conferences and committees.

The Second International Galvanising Conference was held in Düsseldorf in June and July of 1952. It attracted twice the number of delegates as the First Conference in Copenhagen[11], and the German industry welcomed the visitors to its works. The papers and the ensuing discussions have been published;[13] they cover a wide range of subjects, some of which are very practical, such as bath heating, fluxing techniques, the recovery of zinc from ash, the treatment of pickle liquors, and economic factors and working conditions; while others are of more fundamental importance, such as the ductility and flaking of the coating, the potential behaviour of the alloy layers, and the effect of aluminium and iron on the structure of the coating.

The French galvanising industry also helped to foster international co-operation, and in October, 1953 the Société Française de Métallurgié and the Chambres Syndicales des Industries de la Galvanisation jointly arranged an international meeting on galvanising.[14] French authors read papers on the continuous galvanising of strip by the Sendzimir process, the modernised tube galvanising plant of the Société d'Escaut et Meuse, and the influence of coating quality on the corrosion resistance of galvanised wire; and the French very generously threw open several galvanising and steel works and research institutes for visits by the delegates.

Still more recently, the Third International Galvanising Conference of the Zinc Development Association has been held in England, giving an opportunity to repay the hospitality received on the Continent at the previous conferences. Delegates representing 14 European and American countries attended the meeting at Oxford in July, 1954, when the technical sessions were again followed by works visits to general and specialist galvanising plants. Many of the sessions were of interest to galvanisers of all types of product, e.g., those dealing with bath heating, dross formation, after-treatment, and inspection of galvanised steelwork, while for the first time the problems encountered in sheet, tube and wire galvanising were discussed in specialist sessions. A further innovation was the presentation of papers on productivity and incentives, and on cost estimating for general galvanising, subjects which frequently are not introduced at technical meetings of this nature. The seventeen papers, together with the discussions and several written contributions, are available in the printed Proceedings.[15]

The work of the Conference culminated in the decision to form a European Galvanising Committee for the purposes of exchanging technical information and expanding the uses of galvanising. Two exploratory meetings have since been held between representatives of ten European countries, and a Committee was formally set up in December, 1954.

Galvanising has for too long been the Cinderella of the steel industry, but that era has clearly passed. The work of the European Committee should lead to some co-ordination of specifications and codes of practice, and to the exchange of technical information and the results of research work. Galvanisers everywhere should benefit from this new co-operation.

Zinc Alloy Die Casting

The international picture in the zinc alloy die casting industry is quite different from that in galvanising, since here Britain stands midway between a large mature American industry and a comparatively small European industry. In the U.S. the consumption of zinc alloy die castings per head of the population is about three times as big as in Britain; but in Britain again, it is about three times as big as in France, which is the largest Continental user of die castings.

These interesting facts came to light[16] at an important International Conference on Pressure Die Casting[17] held in London in October, 1954, and attended by some 150 delegates from Europe and America. This Conference, the first of its kind, covered many aspects of the production and use of die castings in zinc and other alloys, and both the papers and the discussions on them showed how rapidly the industry has developed since the introduction of dependable zinc alloys in the early 1930's.

The technical sessions in London were followed by visits to leading die casting works in London and the Midlands, where delegates also saw an exhibition[17] of die castings in zinc-base alloys arranged at the Birmingham Exchange and Engineering Centre. Some five hundred die castings, probably the most ever assembled in Britain, were displayed by member-firms of the Zinc Alloy Die Casters Association (Fig. 3); they ranged in size from car radiator grilles to retaining pins for wrist-watch hair-springs, 0·085 in. long. Every significant application of the die casting process, and many examples of the finishes used, were represented, and the exhibition was well attended by industrialists and manufacturers of small metal parts from the Midlands.

The Conference also provided an opportunity for the first showing in Europe of a new colour film entitled "Die Casting—How Else Would You Make It?" produced by the American Zinc Institute with the co-operation of the American Die Casting Institute. The film deals with the value of the die casting process in metal fabrication, and the copies of it now available on loan from Z.A.D.C.A. should ensure that its message is widely heard.

The International Conference was one of the more spectacular activities of the European Pressure Die Casting Committee which was formed in 1953 on the initiative of the Zinc Development Association and the Zinc Alloy Die Casters Association. The Committee consists at present of representatives of die casting associations or leading firms in nine European countries, and has as its aim the encouragement of co-operation between die casters in order to improve the industry's technical efficiency and the increase of consumption of die castings everywhere. Its activities are not confined to zinc but cover the whole range of die cast metals.

Since its formation, the Committee has been engaged in preparing a list of the die casting machines available in Europe, in the collection of statistics, and in the dissemination of technical information. The first edition of a European Die Casting Bulletin has just been published, and deals with die castings in motor cars. It has been issued in English, French, German and Italian. Work is also proceeding on a European Standard for die

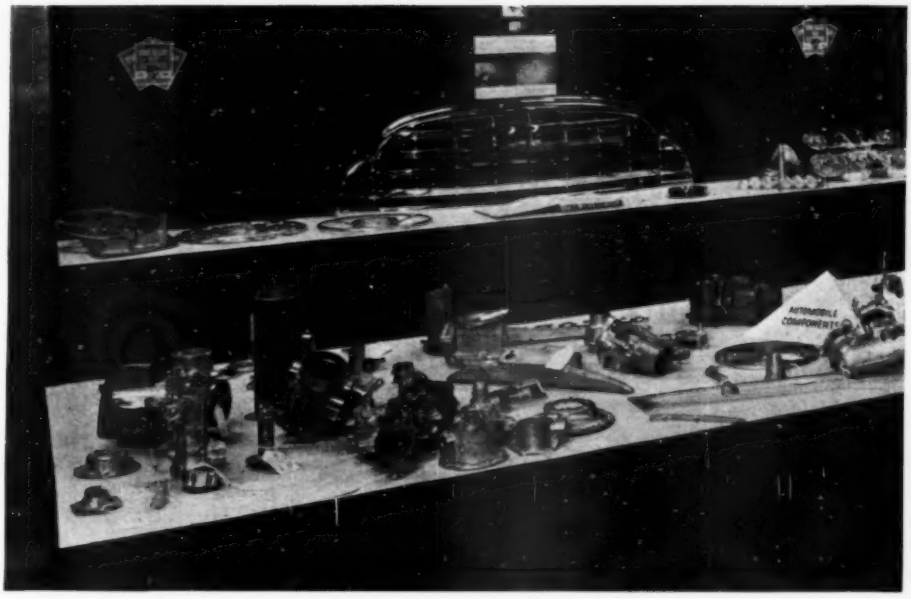


Fig. 3.—Some of the castings shown at the exhibition of zinc alloy die castings held at the Birmingham Exchange and Engineering Centre from October 25th to November 6th, 1954.

casting alloys, a glossary of terms used in the industry, and a film showing the ways in which die casters can help the engineering industries in Europe.

One of the first results of the setting up of this European Committee was the formation, through the Organisation for European Economic Co-operation, of a European team to visit the U.S.A. to study zinc and light metal pressure die casting. The team included representatives of all the principal die casting countries in Europe, including several from Britain, and was divided into four groups, especially concerned with: machines and die making; the metallurgy, manufacture, and control of alloys; die casting and production; and the finishing and applications of die castings. It visited several machine makers and research institutions, as well as typical large and small foundries. Although the report has not yet been published, the conclusions of the mission were outlined in an open session at the International Conference when members told of their impressions.

They did not differ to any marked extent from those of the 1951 Anglo-American productivity team on zinc and aluminium pressure and gravity die casting; whose findings were published in 1952.[18] That team found that productivity was generally higher in the U.S. than in the U.K., even though the best U.K. firms were technically as advanced as those in the U.S. Factors contributing to the difference were considered to be the better liaison between the die caster and his customer in the U.S., the greater readiness of American management to adopt new methods, the more plentiful supply of capital for new equipment, the clearer divisions of executive responsibility in most works, the progressive attitude of labour, the maximum utilisation of plant and labour, careful production planning, and the greater use of standard die components. In view of the big differences between the size of the industry in the U.S. and in most European countries, it is hoped that more emphasis will be given in the new report to practice in the smaller U.S. foundries.

Looking somewhat further afield, it is interesting to learn of the good progress being made by the die casting industry in Australia. The leading firms there have for many years been members of the Zinc Alloy Die Casters Association, and have experienced the benefits which flow from co-operative action. They have now decided to establish a technical development association of their own,[19] organised on similar lines. A member of the Z.D.A. staff is now in Australia and will be visiting the leading firms.

The big difference already noted between the general use of die castings in the U.S. and their more limited application in the U.K. arises partly from the reluctance of our manufacturers to adopt new methods, partly from a conservative attitude towards established materials such as brass, and partly from a lingering suspicion of the quality of die castings, difficult to understand in view of their widespread war-time use in munitions.

Energetic steps have been taken by the Zinc Alloy Die Casters Association to maintain a high standard of quality in zinc alloy die castings. In March, 1954, a Certification Scheme was launched by the Association in conjunction with the British Standards Institution. Licensed die casters now undertake that all their production in zinc alloy conforms with B.S.1004, which imposes close restrictions on the impurities lead, tin and cadmium, both in the alloy used and in the finished castings. A high degree of analytical control is needed from any firm granted a licence by the B.S.I., and daily samples have to be submitted to spectrographic analysis and other tests. Regular plant inspections are made by the B.S.I. As a safeguard to the customer, castings produced under the Scheme are marked or otherwise identified with the "Kite" mark of the B.S.I. and the maker's licence number. Examples of such castings are shown in Fig. 4.

For several years there has been a demand in many countries for some revision of the specifications for zinc alloys for die casting; this is mentioned in a Canadian report[20] on the effect of impurities in the alloys, which

Fig. 4.—Key-ring medallions consisting of zinc alloy die castings produced under the B.S.I. Certification Scheme; the medallion on the right commemorates the First International Die Casting Conference.

draws attention to the deleterious effects of small amounts of indium, among other things. Since 1953, the revision of B.S. 1003 and 1004 of 1942 has been under consideration by the British Standards Institution, and drafts of the proposed new standards have now been circulated to industry for comment; they are expected to include references to the limits for indium and thallium both in high-purity zinc and in the casting alloys, to the B.S.I. Certification Scheme, and to the procedure for re-melting process scrap. Some minor modifications to the magnesium and aluminium limits in the alloys are also expected.

Work by the Zinc Alloy Die Casters Association has been in progress for some years on a draft Code of Practice for Zinc Alloy Pressure Die Castings for Engineering. This Code is now in an advanced stage and has been circulated for comment by the British Standards Institution. It will be published in 1955, shortly after the revised British Standard for zinc alloy, and will deal with the importance of using the correct quality of material, good casting technique and satisfactory design.

Zinc Pigments

A major use of zinc pigments, particularly zinc oxide, continues to be in rubber manufacture, and in recent years a steadily increasing proportion of the zinc oxide consumed in this country has been used in the rubber trade. The motor car and other industries require large quantities of rubber goods in which zinc oxide is used for the activation of organic accelerators, the reinforcing of rubber compounds, the pigmentation of white products, and in the manufacture of insulated cable, "V" belts and other components. A tyre, for example, contains 5 to 10% zinc oxide, an inner tube possibly 15%, and best quality insulants used in cable manufacture may contain as much as 50% zinc oxide, calculated on the rubber content. Special types of zinc oxide have been developed for the industry, and a concise but comprehensive review of their fundamental chemical and physical properties, and of the properties imparted by them to both uncured and vulcanised rubber products, has been published by the New Jersey Zinc Co.[21] Zinc sulphate and lithopone are also used in rubber manufacture, mainly as pigments, although lithopone can exhibit quite marked reinforcing effects.

The second important application of zinc pigments is in paints where zinc oxide, lithopone, zinc chromate and zinc dust are all common ingredients. Zinc oxide is widely used in formulating exterior finishing paints, either alone or in combination with other pigments, particularly TiO_2, where its addition causes an improvement in dispersion, flow and brushability. Increasing attention is now being given to the brushing characteristics of paints, as instanced by a recent discussion between paint users and paint chemists at the Midlands Section of the Oil and Colour Chemists' Association,[22] and the excellent properties of zinc oxide paints in this respect are well known.

The use of lithopone in paints, particularly for interior decoration, has been well established for many years. The development of the modern emulsion paints, however, has further increased their field of application, since lithopone is the ideal pigment for the washable oleoresinous finishes as well as for the water paints which preceded them.

Zinc chromate and tetroxychromate primers continue to be used wherever a high degree of corrosion protection is required. Recent exposure test work by Rigg and Skerry on priming paints for light alloys[23] has demonstrated conclusively the value of zinc chromate primers, and these authors recommend them for any composite structures of steel and light alloys, particularly where exposure conditions are severe.

Interest in paints containing metallic zinc is growing, as the result of recent work showing their usefulness as primers for steel and wood, for stoving primers and for heat-resisting paints. Anti-corrosive compositions containing 95% of zinc dust ("zinc-rich" paints) are becoming more popular than the earlier formulations, since they can be successfully applied to steel surfaces having an adherent oxide coating. Such surfaces are frequently found on weathered structural steelwork, and, where zinc paints are used, surface preparation before painting may consist only of a perfunctory wire-brushing operation which removes loose surface deposits and dirt only.[24-26]

Cathodic Protection

Recent American work on the use of zinc anodes for cathodic protection of structures underground or immersed in water has shown that certain impurities, notably iron, lead and cadmium, give rise to a tendency for zinc anodes to become passive. In consequence, the American Zinc Institute[27] advocates the use of 99·99% pure zinc, with a maximum iron content of 0·005%, for installations buried in soil with a gypsum-clay content and designed for a life exceeding 10 years; and further recommends that the iron content should not exceed 0·0015% for sea-water installations. At the 1953 Symposium on Cathodic Protection, organised by the Society of Chemical Industry, the use of an alloy containing 99·7% pure zinc with 1% of magnesium for protecting ships' hulls was also recommended.[28] The

use of zinc anodes of higher purity is a notable development in this field, and successful applications have been reported for underground oil, gas and electric lines, heat exchangers and condensers, and wharves and jetties.

Plating

One of the most important applications of zinc plating continues to be the coating of wire by the Tainton process,[29] and wire coated in this way represents a considerable proportion of the United Kingdom's output. During recent years the zinc plating of steel sheet has been gaining in importance, and several firms are now using variations of the Heath sulphate process[30] for this purpose. Widths up to 52 in. are now produced, the sheet finding large markets in the production of washing machines and kitchen furniture where the zinc coating protects enamelled steel against any possible rusting.

The tin-zinc process, developed by the Tin Research Institute, has proved valuable in many countries for the protection of steel, and for giving decorative white finishes to brass and other high-copper alloys, the ready solderability of the coating being one of its main advantages. It contains 75% tin and 25% zinc, and is used in the electrical, aircraft and many other industries. The process has recently been approved[31] by the Ministry of Supply in Specification D.T.D.927 for the protection of certain steel parts.

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New and Revised British Standards

ROSIN-CORED SOLDER WIRE "ACTIVATED" AND "NON-ACTIVATED" (NON-CORROSIVE) (B.S.441: 1954). PRICE 3s. THIS standard is a revision of that published in 1932, since when methods of activating the rosin-core of the solder have been developed, and the new edition specifies solder wire with a core or cores, incorporating the advantages of these methods. The scope of the standard has been widened by the inclusion of five grades of solder, for each of which information is given with regard to melting characteristics and typical uses. In addition tests have been included relating to the hardening of the flux residues, and to their freedom from corrosive action. The importance of this standard to industry generally may be gauged from the fact that 48 organisations (Government departments, scientific and industrial) co-operated in its preparation.

ELECTRIC BOILING-PLATES FOR DOMESTIC PURPOSES (B.S. 744 : 1954). PRICE 3s. 6d.

The B.S.I. has recently published a revision of B.S. 744 "Electric boiling-plates for domestic purposes." The standard specifies the requirements for the construction and performance of sheathed-element type and cast iron enclosed type of boiling-plates for domestic purposes, which are intended for operation on voltages not exceeding 250 V. There is a comprehensive section dealing with the methods of testing, which gives information on leakage current, dielectric strength, thermal efficiency, endurance tests, thermal shock tests, etc. There is also a section on the method of marking boiling-plates which comply with the requirements of the standard, and an appendix gives information on controlling the humidity of atmosphere when carrying out an installation resistance test.

METHODS FOR THE ANALYSIS OF IRON AND STEEL PART 32: ABSORPTIOMETRIC DETERMINATION OF TUNGSTEN IN STEEL (B.S.1121 : 1954). PRICE 2s.

THE method specified in this standard is applicable to steels containing up to 3% of tungsten, although it may be modified to deal with higher tungsten contents. The principle of the method is solution of the sample in phosphoric-sulphuric acid, reduction of the ferric salt by stannous chloride, the formation of a thiocyanate complex of tungsten, completion of the reduction by titanous chloride, and photometric measurement of the resultant yellow colour due to tungsten. The method is based on research work undertaken by the British Iron and Steel Research Association.

COVERED ELECTRODES FOR THE METAL-ARC WELDING OF MEDIUM-HIGH-TENSILE STRUCTURAL STEEL (B.S.2549 : 1954) PRICE 4s.

0·5% MOLYBDENUM STEEL ELECTRODES (COVERED) FOR METAL-ARC WELDING (B.S. 2493:1954) PRICE 4s.

THESE standards form part of a series for electrodes for metal-arc welding. B.S.2549 deals with electrodes for the welding of steel of welding quality having a tensile strength of up to 43 tons/sq. in., e.g., the type of steel

covered by B.S.968 "High tensile (fusion welding quality) structural steel for bridges, etc., and general building construction." The lack of such a specification in the past has meant that most specifications for the design of structures in high tensile steel have had to specify the use of mild steel electrodes, and, accordingly, the permitted stresses in the welds have not been at all comparable with the permissible stresses in the parent metal. The specification follows the form adopted in B.S.639 : 1952, in its general requirements and test requirements. An additional test is the controlled thermal severity cold cracking test, which is based on research work carried out by the British Welding Research Association.

B.S.2493 covers the type of electrode commonly used for the welding of molybdenum and chromium-molybdenum steels, which operate at elevated temperatures. Basically the specification is the same as B.S.639, except that the deposited metal is required to contain 0·5% molybdenum. It is emphasised that in neither of these specifications is it possible to cover the suitability of an electrode for a particular type of steel for a particular application. It will often be necessary to prove the suitability by appropriate tests which are outside the scope of the British Standards for electrodes.

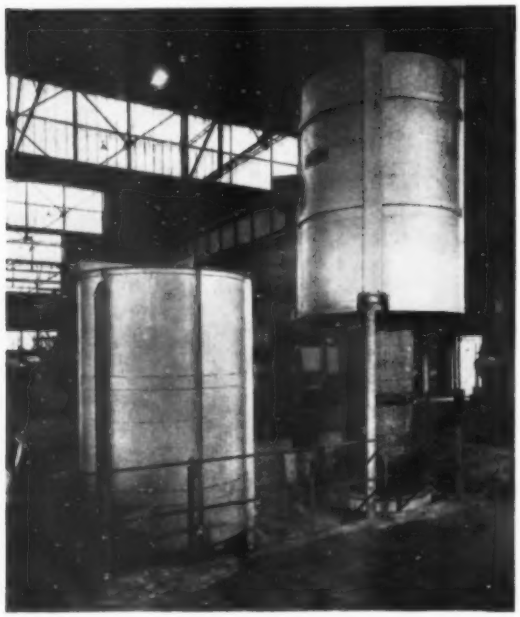
Copies of these standards can be obtained from the British Standards Institution, British Standards House, 2, Park Street, London, W.1.

Batch Softening Stainless Steel Strip

THE works of Shepcote Lane Rolling Mills, Ltd., of Sheffield, has a production capacity of over 200 tons of wide stainless steel strip per week. Among new plant installed is an electrically heated bell furnace, supplied by G.W.B. Furnaces, Ltd., of Dudley. This furnace, of the lift-off type, was supplied complete with two charge bases, a slow cooling hood, automatic temperature control equipment, switchgear, and an oil circuit breaker.

The process carried out is the batch softening of coiled stainless steel strip of 17% chrome quality at approximately 780°/800° C. The coils are heat-treated after they have been hot rolled and welded together to form a coil of up to 10,000 lb. in weight. Hot rolling reduces the strip to about 0·125 in. in thickness and, after softening in the G.W.B. furnace, it is cold rolled down to the particular gauge required.

The heating bell is rated at 220 kW. distributed over a single automatically controlled zone; as is normal practice, where possible, this load is distributed evenly over the three phase mains supply. The normal process cycle covers a total of 14 hours, which includes a soaking period of 2-4 hours. These are average figures and it can be stated that a temperature of 750° C. is usually reached within 6 hours.



Each of the two bases carries two coils of stainless steel strip with a total maximum weight of approximately 20,000 lb. The strip is 1 metre wide, and the 4-ft. diameter coils which are loaded individually by means of the shop crane, are carried on cast heat-resisting steel jigs with radial supports underneath and a central column running through the middle of the coil with an attachment at the top for lifting purposes. The whole charge weight is taken on a cast heat-resisting steel stool fixed into the hearth brick work. Each base is fitted with a powerful electrically-driven air-circulating fan which sucks the air through the centre of the coils, and blows it up around the outside and over the heating elements situated around the wall of the furnace. It will be appreciated that uniform thermal conditions are essential in this process in order to obtain uniform metallurgical conditions throughout the coils of strip, and forced convection ensures that these conditions are obtained. Air circulation also reduces heating-up times which, in its absence, would otherwise be unduly protracted.

When the soaking period, and therefore the process cycle, is completed, the heating bell is lifted off and replaced by an open topped sheet steel cover which is intended to prevent direct radiation from the hot charge on to workmen in the surrounding area. The relationship between the heating and cooling cycles ensures continuous working of the furnace in conjunction with the two bases.

The furnace is lined with refractory firebrick, backed by a substantial thickness of Dome insulating brick, reducing heat losses to a minimum. The heating elements are of heavy gauge nickel-chromium strip arranged in sinuous form around the lining, and are carried on nickel-chromium hooks embedded in the brickwork. The latest type of electrical pick-up gear is fitted, this being in the form of spring-loaded butt-type contacts on the underside of the furnace which mate up with a similar set of contacts installed in the floor beside each base. The electric supply is fed to each of these sets of floor contacts.

Instrumentation includes an indicating controller of Kent manufacture, and a Kent 3-point recording instrument giving a positive check of thermal conditions on either base and on the heating bell itself.

Tonnage Oxygen Production

B.O.C.-Linde Merger To Handle Plant Sales

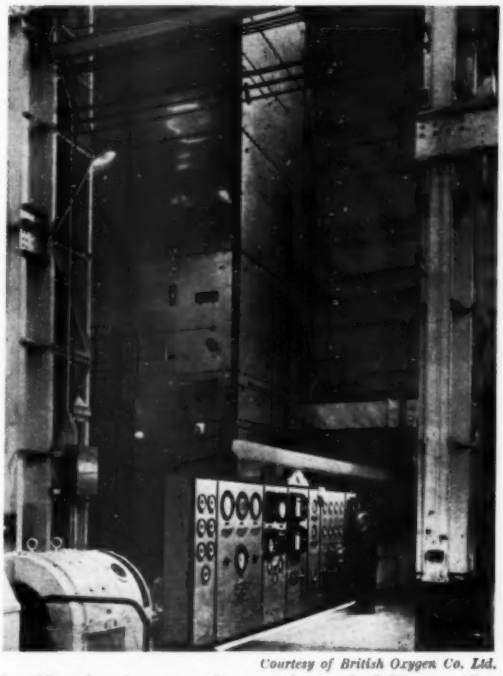
THE post-war years have witnessed a considerable increase in the use of oxygen as a reactive material in the production of iron and steel. Investigations have been made into the possible benefits to be gained from its use at almost every stage—in the blast furnace, in the open hearth furnace, in the Bessemer converter and in the electric furnace—and for certain purposes it is being used on a commercial scale. These developments, and similar ones in the production of synthetic chemicals and the gasification of coal and other fuels, have resulted in individual works requiring oxygen in quantities of several hundred tons a day. Such a demand can only be met by the erection of a local plant of the type commonly known as a tonnage oxygen plant. It is designed to supply gaseous oxygen—and sometimes nitrogen as well—in quantity and quality to meet the demand, and to deliver the gas directly by pipeline to the consuming process or processes at the appropriate pressure.

The conditions of supply of tonnage oxygen vary widely according to the process in which it is used, and there are, moreover, other processes which depend on gases which must be separated by a technique similar to that of oxygen manufacture. In order to meet every demand with the utmost efficiency, The British Oxygen Co., Ltd., and Gesellschaft für Linde's Eismaschinen, A.G., Wiesbaden—both pioneers of commercial oxygen production—have formed a joint technical and sales organisation for oxygen plants and other gas separation plants. The joint experience of these two companies extending over more than half a century in the design and manufacture of such plants, as well as in the production and distribution of the gases themselves, is to be pooled and placed at the service of modern industry. The new organisation, which takes the form of a jointly-owned subsidiary company, British Oxygen Linde, Ltd. (with two German and two British directors), will have its headquarters at Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

Background Of Experience

The new company will undertake the sale of tonnage oxygen plants and other gas separation plants to meet the precise needs of individual consumers on their own premises. The joint knowledge and experience of the two firms will be placed at the disposal of industry for advice on installation, erection and running. The Linde Company of Germany are pioneers in low-temperature technology and have a background of 75 years of plant design and construction. Their founder, Carl von Linde, will be remembered as the inventor of the commercial process for making liquid air and obtaining pure oxygen from it by distillation. The Linde-Frankl Process, developed by the Company in 1930, first made tonnage oxygen available to industry, and since that time the Company have built more than a hundred Linde-Frankl plants throughout the world, some of which produce individually many hundreds of tons of oxygen each day. These plants have opened up entirely new fields of production in the gasification and chemical industries.

The British Oxygen Linde plants are intended to meet the demands of industry by producing oxygen of high or medium purity at tonnage oxygen costs, and by providing the utmost flexibility in output without sacrifice in economy. The plants include a range of sizes sufficient to meet the largest probable requirements. In addition to their normal output of oxygen, they can also provide supplies of pure nitrogen for use in bright annealing furnaces.



Courtesy of British Oxygen Co. Ltd.

Rectification tower and control panel of 50 tons/day liquid oxygen plant.

No Overlap

It should be emphasized the new Company will not take over any of the activities of the British Oxygen Company in the production and distribution of compressed oxygen and liquid oxygen, nor in their tonnage oxygen service by which they build plants of their own and pipe supplies to customers, works, and also hire tonnage oxygen plant to customers' The latter arrangement offers special advantages to a customer whose demands are steadily growing, as it enables him to avoid the heavy capital expense of a plant which could rapidly become inadequate for his needs.

Change of Address

THE Manchester Area Office of Elliott Brothers (London), Ltd., Bristol's Instrument Co., Ltd., and Fisher Governor, Co., Ltd., is now 32, Deansgate, Manchester, 3. (Tel. : Blackfriars 7752 and Deansgate 6331.)

Blickvac Engineering, Ltd.

BLICK ENGINEERING, LTD., of Jarrow, has acquired the high vacuum engineering business of "Blickvac" and has changed its name to Blickvac Engineering, Ltd. The Board will consist of Mr. O. Moor, Mr. R. A. Pearson, Mr. J. Todd and Mr. G. Wall, B.E.M.

NEWS AND ANNOUNCEMENTS

Summer School of Welding

THE fifth Summer School of Welding, organised by the B.W.R.A. will be held at Ashorne Hill, from Monday, June 27th to Saturday, July 2nd, 1955. The School takes for its basic theme "Welding Developments in British Industry," and has been devised to cover various aspects in logical sequence during the course. As in previous years, lectures of general interest will be given in the morning, and lectures of more specialised interest in the afternoon. To meet particular requirements, students will be divided into the following groups:—Group A—Pressure Vessels; Group B—Transport; Group C—Shipbuilding; and Group D—Specialised Welding Techniques. It is possible that an additional group on Inspection and Testing will also be included if there is sufficient demand.

The general introductory lectures for the school will be devoted to critical and comparative studies of welding processes and materials. In later lectures, particular problems, such as brittle fracture, fatigue and corrosion, will be discussed. The course will be completed by lectures on inspection and control methods, organisation, and radiographic and ultrasonic testing. For the various groups, a more detailed study will be given to specialised subjects following the general sequence of materials, processes, design and application.

There are two innovations to this fifth School—groups on Transport and Specialised Welding Techniques. In the former, lectures will be of interest to all those in the railways and associated industries, including road transport. The group on Specialised Welding Techniques satisfies a demand which has been steadily growing for a more detailed study of gas-shielded welding processes.

The school is open to all and special arrangements have been made this year to increase the places available by booking additional accommodation in local hotels, as last year over 50 applications had to be refused owing to lack of accommodation. In spite of the increased size of the school it is advised that those persons wishing to attend, or to send representatives from their organisations, should obtain application forms as soon as possible, as a number of the specialised groups become fully booked up very quickly.

Application forms and programme of lectures are obtainable from The Organising Secretary, 5th Summer School of Welding, British Welding Research Association, 29, Park Crescent, London, W.1.

Special Fuel Courses

A SERIES of eight lectures on the Utilisation of Fuels—solid and gaseous—will be given in the Department of Coal, Gas and Fuel Industries of the University of Leeds during the next few weeks. Two lectures will be given each Monday afternoon from February 14th to March 7th, 1955. The first two, to be given by Mr. F. L. Atkin, Chief Distributing Engineer, West Midlands Gas Board, will deal with the distribution of gas, the remaining subjects and lectures being: modern gas practice (Mr. E. A. K. Patrick, Industrial Laboratory, Watson House, North Thames Gas Board); domestic gas appliances (Mr. F. Brinsley, Technical Service Manager, Radiation, Ltd.); and domestic solid fuel (Mr. J. S. Hales, Director of Domestic Appliances Laboratories, B.C.U.R.A.). The pairs of lectures may be attended separately for a fee of £1 each pair, the complete course costing £3. A further course, on Disposal of Waste Liquors Produced in Gas Works and Coke Ovens, will take the form of two lectures to be given on Monday, March 14th, by Mr. W. H. Blackburn (Research Chemist to the Joint Research Committee of the Gas Council and the University of Leeds). Further particulars of these courses can be obtained from the Head of the Department of Coal, Gas and Fuel Industries with Metallurgy.

1955 Instrument Exhibition

THE third British Instrument Industries Exhibition to be held at Earl's Court, London, from June 28th to July 9th, 1955, will be the largest of its kind. It will show the latest equipment of manufacturers of scientific and electrical instruments, industrial meters, automatic controls, scientific glassware, and drawing office equipment.

Instrumentation and controls are important to every industry by providing means for research, and for establishing and maintaining optimum working conditions, thereby securing increased and cheaper production, and higher and more consistent quality with less wear and tear on the plant. This Exhibition offers the industrialist the opportunity to examine the latest methods and equipment which are now at his disposal

The exhibition is sponsored and actively supported by The British Electrical and Allied Manufacturers' Association, The British Industrial Measuring and Control Apparatus Manufacturers' Association, The British Lampblown Scientific Glassware Manufacturers' Association, The Drawing Office Material Manufacturers' and Dealers' Association, and The Scientific Instrument Manufacturers' Association of Great Britain

Spring Conferences at Birmingham

THE annual Spring Conferences in the Department of Industrial Metallurgy will be held on 14th and 15th March, 1955. The subject for 14th March will be: "Graphitisation in Cast Irons" and for the 15th March: "The Structure and Properties of Electrodeposited Metals and Alloys." At both Conferences papers will be given by eminent research men, reviewing the developments in the theoretical as well as in the applied fields, and will be followed by discussions. For admission to the Conferences application should be made to the Secretary, Department of Industrial Metallurgy, The University, Birmingham, 15, from whom full particulars of the programme may be obtained.

Institute of Metals Discussions

As previously announced, the Metallurgical Engineering Committee of the Institute of Metals will hold an all day Informal Discussion on "The Treatment of Swarfs, Sawings and Residues in the Non-Ferrous Metal Industries," at the University, Edgbaston, Birmingham, on Wednesday, February 16th, 1955, from 10.30 a.m. to 4.30 p.m. The discussion is to be planned to cover basically the recovery of metal and to include such processes as sampling and assaying, segregation, mechanical separation of residues, briquetting, fluxing

and melting, etc. The discussion will cover both methods and equipment.

Members of the Institute (and visitors who will be very welcome and can attend without ticket) can take lunch in the University Refectory (price 5s. 6d., including coffee) if they notify their wish to do so (with remittance) to the Secretary of the Institute of Metals, 4, Grosvenor Gardens, London, S.W.1, not later than Monday, February 7th.

Domestic Corrosion Prevention Discussion

ORGANISED by the Corrosion Group of the Society of Chemical Industry, a Discussion on Corrosion Prevention in the Home will be held in the Rooms of the Chemical Society, Burlington House, Piccadilly, London, W.1, on Wednesday, February 16th, 1955, at 6-30 p.m. The discussion will be opened by contributions from: Mrs. A. Jackman (Queen Elizabeth College), who will speak on some general problems arising in the household; Dr. P. T. Gilbert (B.N.F.M.R.A.), on the prevention of corrosion of pipes, tanks and hollow-ware; and Mr. H. J. Sharp (Hoover, Ltd.), on the selection and performance of finishes on domestic equipment. The subject is one which affects everyone, and interest in it will already have been stimulated by the Exhibition organised by the Group last month.

The "Under-45" Club (Non-Ferrous Metal Trades)

A MEETING of interest to the non-ferrous metal trades will take the form of a luncheon at the Imperial Hotel, Birmingham, on February 28th, to which all members of such trades (under 45) are most cordially invited. The purpose of this meeting is to moot the possible creation of a club drawn from the members of the non-ferrous metal trades, whereby improved relations between all such members could be promoted and donations made to selected charities.

It will be realised that the success of an undertaking of this nature (which could be extremely beneficial to all concerned) depends largely on the initial support given and it is, therefore, hoped that a really representative number will attend. Those wishing to receive further particulars of the club and desiring to partake of the luncheon at the end of the month (commencing at 12.30 and finishing at approximately 2.30 p.m.) should contact either Mr. P. Mould of Mould Bros. (Camp Hill), Ltd., or Mr. D. Devereux of Arthur E. Milner (Metals), Ltd.

B.O.A.C. Chief to Open Factory Equipment Exhibition

SIR MILES THOMAS, Chairman of B.O.A.C., has accepted an invitation to open the third National Factory Equipment Exhibition at Earls Court on March 28th, 1955. Since its inception in 1953, the Factory Equipment Exhibition has rapidly risen to be in the top flight of industrial fairs and the 1955 Exhibition will be the most comprehensive display of factory equipment ever to be put on show in this country. There will be completely new machines which will be of considerable assistance in improving production and general industrial efficiency, as well as a number of other new items aimed at making the worker's task easier. Aspects of factory management and welfare will also be included in the wide range of exhibits.

Three important conferences will be staged concurrently with the six-day exhibition. The National Industrial Fuel Efficiency Service is presenting a series of talks on "Fuel Efficiency Pays"; the British Productivity Council, a one-day conference on "Work Study" illustrated by practical films; and the Institution of Works Managers will hold their National Conference during the last three days of the Exhibition.

In view of the fact that over 50m. square feet of new factory space have been approved by the Board of Trade in the first nine months of this year—nearly twice as much as in the same period last year—there is certain to be a very great interest taken in the various classes of equipment which will be on display at the 1955 Factory Equipment Exhibition.

Ore Dressing Congress

AN International Ore Dressing Congress arranged by the Gesellschaft Deutscher Metallhutten- und Bergleute (G.D.M.B.) will be held at Goslar (Harz) from May 8th–11th, 1955. It will be preceded on May 6th and 7th by the Annual General Meeting of the G.D.M.B., to which visitors to the Congress are cordially invited. At the Congress itself some 20 lectures on current ore dressing problems will be delivered, followed by detailed discussion. By means of simultaneous interpretation, all lectures and discussions may be heard in each of the three official languages of the Congress—English, French and German. In the afternoon, visits will be made to ore dressing plants in the vicinity of Goslar, and at the conclusion of the Congress a three-day visit to ore dressing plants and research stations in Western Germany is being planned. The Secretary of the Congress is Dipl. Ing. W. Koch, G.D.M.B., Clausthal-Zellerfeld 1 (Germany), Postfach 51.

Canadian Approval for Motors

NEWMAN INDUSTRIES, LTD., announce that their popular range of totally enclosed flameproof motors are now CSA approved. The Canadian approval (No. 13809) covers both the fan-cooled and the naturally-cooled models and includes the foot-mounted, flange-mounted and combined-mounting types. Newman barrel-type, steel frame, flameproof motors, designed expressly for use in the mining industry, are also covered by this CSA approval so that the complete range can now be supplied to Canada for use under Canadian hazardous duties Class 1, Group D and Class 2, Groups F and G. These Newman motors are all rated to comply with B.S.168: 1936 and are flameproof in accordance with B.S.229: 1946, and are Buxton Certified for Gas Groups I, II and III.

Steel Import Duties Suspension

AFTER consultation with the Iron and Steel Board about the supply position, Her Majesty's Government have decided to make a new Order affecting the temporary suspension of import duties on iron and steel. The Order prolongs the temporary suspension of import duty on cold rolled steel sheets of a value of less than £80 per ton until March 18th, 1956; and suspends until September 18th, 1955, the import duties on a wide range of iron and steel products. The duties on some of these had already been suspended until March 18th, 1955.

The new Order, which is known as the Import Duties (Exemptions) (No. 1) Order 1955 (SI.33) came into operation on January 14th. It replaces the Import Duties (Exemptions) (No. 6) Order 1954. Copies of the new order may be obtained from H.M. Stationery Office or from any bookseller, price 3d. (post free 4½d.).

Working Model Steelworks

A WORKING model of a complete steelworks has been on view in the Science Museum, South Kensington, from January 24th, 1955. On a floor area of 60 ft. × 24 ft., it portrays a steelworks covering a site of over a quarter of a square mile in area, with a weekly capacity of 10,000 tons.

The purpose of the model is educational : it is intended to show what a complete steelworks looks like, and how the various pieces of steel-making plant are arranged in process sequence from the iron ore to the finished product. Raw materials are unloaded at the docks by transporter crane and, together with coke from the coke ovens, charged into the blast furnaces. There follow in sequence : steelmaking furnaces, ingot-casting bays, soaking pits and rolling mills. Ancillary services, such as a power station, repair shops, stockyards, 20 miniature locomotives and 1,500 pieces of rolling stock running on half a mile of track, complete the scene.

The model, which has been lent to the Museum by the British Iron and Steel Federation, will be demonstrated and explained at intervals, and a selection of the most recent films on various aspects of the iron and steel industry will be shown.

McKechnie " 25 " Club

THE Birmingham Branch of the McKechnie " 25 " Club held its 3rd Annual Dinner and Social Evening at The Imperial Hotel, Birmingham on Friday January 7th. Mr J. D. McKechnie, Chairman and Managing Director of the Company, and President of the Club, presided, and Mr. H. Hollingworth, the Vice-President, welcomed the guests among whom was M. P. Werthmuller, of Paris, Managing Director of the French Trading Company of McKechnie Brothers, (and who, incidentally, has also been with the Company for 25 years). In replying to the Toast to the Company, Mr. McKechnie spoke of the foundation of the Company at St. Helens in 1871, and of its development since into an enterprise of considerable size with a very large modern factory in course of building at Aldridge in Staffordshire. The factory in South Africa is also making good progress and a newer project in New Zealand has already made a satisfactory start.

The President concluded by presenting awards for 25 years' service to seven new members.

Ore Handling Plant Order

THE General Electric Co., Ltd., announces that its Fraser and Chalmers Engineering Works, Erith, Kent, have received a contract from Colvilles, Ltd., for a 500 ton per hour capacity ore handling plant for their stock yard at Clyde Iron Works, Glasgow.

The plant, commencing from an existing travelling transporter spanning the ore stock yard, includes a 950 ft. long conveyor running parallel with the stock yard which will deliver the ore to another conveyor. The second conveyor will be 700 ft. long and will in turn deliver to an ore screening station for which all the screens, local conveyors and associated gear will also be supplied. In order that ore may be diverted to a possible future crushing plant a reversible belt feeder will be sited at the junction of the two long conveyors. The contract for this equipment includes motors and control gear.

Personal News

THE Council of the Institute of British Foundrymen announces with extreme pleasure that H.R.H. THE DUKE OF EDINBURGH has been elected an Honorary Member of the Institute. The election which, is most gratifying to members both in this country and the Commonwealth, took place at a meeting held on January 15th, the Council having been granted permission to make the nomination.

MR. R. P. MORISON, Q.C., has been appointed Independent Chairman of the Executive Committee of the British Iron and Steel Federation in succession to the late Mr. F. Grant, M.C., Q.C. Mr. Morison, who is 54, was educated at Winchester and Edinburgh University and was called to the Scottish Bar in 1923 and to the English Bar in 1940 : he took silk in 1936. He has been a member of the Industrial Disputes Tribunal since 1944, and has latterly been a Deputy Commissioner in Scotland under the National Insurance Acts.

DR. K. WINTERTON has relinquished the post of Chief Metallurgist (Ferrous) to the British Welding Research Association to take up an appointment as Assistant Director of the Metallurgical and Engineering Department, Ontario Research Foundation, Toronto, and will be commencing his new duties on March 1st.

DR. R. J. SARJANT, O.B.E., has been appointed Director of Research of the British Steel Castings Research Association, and DR. A. H. SULLY has been appointed Associate Director of Research. Dr. Sully, who is at present Head of the Metallurgy Division of the Fulmer Research Institute, will take up his new appointment in March.

MR. G. TALBOT, who is well-known in the iron and steel industry, has joined The Wellman Smith Owen Engineering Corporation, Ltd., as General Manager of the Furnace Building and Contracting Division.

MR. J. E. C. BAILEY, C.B.E., Chairman and Managing Director of Baird & Tatlock (London), Ltd., and Hopkin and Williams, Ltd., manufacturers of scientific instruments, laboratory furnishings and fine chemicals, is at present on a tour of the Middle and Far East. Mr. Bailey will visit the agents of the two companies in the various countries, and he will also contact as many important industries and laboratories in each territory as possible.

MR. R. T. ROLFE, O.B.E., has retired from the position of Chief Metallurgist to Messrs. W. H. Allen, Sons & Co., Ltd., Bedford, and is succeeded by MR. J. R. BRYANT. Mr. Rolfe remains associated with the Company in a consultative capacity.

Obituary

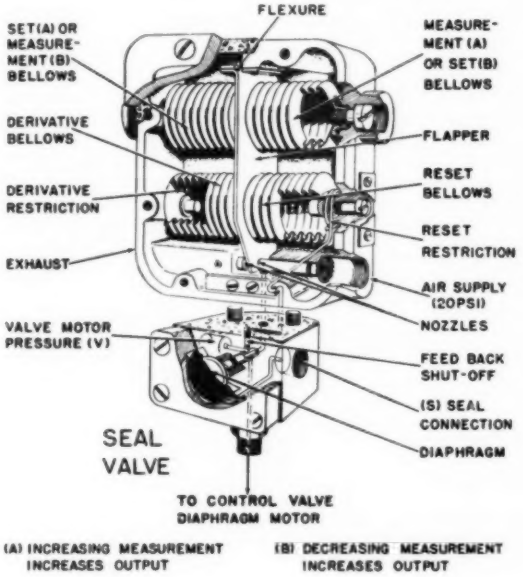
WE regret to record the death of MR. G. C. WALTON, Sales Manager of McKechnie Brothers, Ltd., Birmingham. Until his appointment as Sales Manager in July of last year, Mr. Walton had for many years represented McKechnie Brothers in North East England and in Scotland.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

New Flow Controller

FOXBORO-YOXALL LTD. have recently introduced the Consotrol Model 59 controller, a new force balance instrument which is mounted directly on the valve motor. It has been specially developed to give speedy response and precise control on liquid flow applications regardless of load conditions and process upsets and its simplicity of design confers important savings in first cost, installation and maintenance cost. The instrument has no pivots, few moving parts and only one simple adjustment which is not used on most applications. The Model 59 is designed exclusively for use on liquid flow control applications where the measurement is transmitted by a high speed differential pressure transmitter and where orifice and control valve are in the same line. It has proportional band and reset and derivative times at fixed optimum values: this permits use of the controller on any close coupled liquid flow process without adjustment and without significant difference in flow control.

The accompanying sketch shows the construction and air circuits of the Model 59 controller. The flapper is flexure pivoted and positioned between the supply and exhaust nozzles by four matched bellows whose net force is always zero, while the controller case is always at output pressure. With equal pressure in all four bellows, the controller is in static force balance. If the pressures in the measurement and set bellows are not equal (indicating a departure of measurement from setpoint) the unbalance of forces moves the flapper in the direction of lower pressure to close the supply port and open the exhaust, or vice versa, changing the pressure inside the case. As this pressure changes, air flows through the large derivative restriction much faster than through the smaller reset restriction. A difference in pressure is created between the reset bellows and the derivative bellows which produces a net force in the direction of lower pressure exactly to balance the force produced by the set and measurement bellows. This control action may be reversed by interchanging the measurement and set connections.



Foxboro-Yoxall Ltd. Lombard Road, Merton, S.W.19.

Exposure Calculator for Gamma Radiography

THE British Steel Castings Research Association announce that an improved Mark II model of their Radiographic Exposure Calculator has now been produced having scales for use with the isotopes Calcium 137 and Thulium 170, in addition to those for Cobalt 60, Iridium 192 and radon which appeared on the earlier Mark I version. To meet the demand from continental countries, a Mark III version of the calculator has also been produced, in which metric scales replace the inch scales on the Mark II model.

Scales for the newer isotopes Thulium 170 and Caesium 137, have been included primarily to meet the requirements of industries other than steelfounding, and of the overseas market. Thulium 170, with a half life of 127 days, is an extremely useful source for the examination of sections of steel less than $\frac{1}{2}$ in. in thickness, or in other cases where low-to-medium energy radiation is required.* Caesium 137 emits radiation somewhat similar to that from Iridium 192, but its half life of 33 years, as compared with only 10 weeks for the latter, makes it more attractive to overseas users, for whom the return of sources to Harwell for periodic re-irradiation is both expensive and inconvenient.

In addition to the increased versatility of the new calculator, improvements have also been made in the general construction and appearance, and the length and thickness of the rule have been reduced to strictly "pocket size."

The British Steel Castings Research Association, Broomgrove Lodge, Sheffield, 10.

Export enquiries: M. Falk & Co., Ltd., 5, Victoria Street, London, S.W.1.

Silencers for Axial Flow Fans

A SIMPLIFIED method of reducing the sound level in fan systems has been introduced by Woods of Colchester, Ltd. It takes the form of a range of standardised absorption-type silencers for use in conjunction with the Company's Aerofoil fans. They are the result of extensive laboratory investigation, the design being selected to match the sound frequency range of the Aerofoil fan. With one or more of these units, the sound emission from the fan can be attenuated (reduced in intensity) to suit the requirements of the installation, and costly acoustic treatment to the system ducting can be avoided. The silencer also provides much more latitude in the selection

* See: "Thulium 170 as a Low Energy Source for Gamma Radiography", by Williamson, Rossiter & Bentley. Proceedings, Radioisotope Conference, Oxford, 1954.

of small, high-speed fans in the interests of space-saving and first cost.

The Woods silencer takes the form of a simple cylinder, devoid of splitter or baffles and presenting relatively no more resistance to airflow than a plain metal duct. The outstanding feature of the design is the exceptional sound attenuation achieved in so short a length—approximately 1½ times the duct diameter. One silencer mounted adjacent to the fan will reduce the sound emission by 10 db.: two in series will make a reduction of 15 db., whilst three will bring down the sound level by 19 db. To obtain the optimum effect in sound reduction the silencer should be mounted right beside the fan, and between the fan and the place at which the noise may be objectionable, whether upstream or downstream of the fan. In some cases where all round quietness is required, silencers may be fitted on both sides of the fan.

Silencer units are available in six sizes to match Aerofoil fans from 15 to 48 in. diameter. To facilitate direct attachment to the fan the end-rings are drilled and tapped to the same pitch centres as the fixing holes in the fan flanges. Where two or more silencers are to be mounted in series, a short connecting duct-section having flanges at each end can be supplied. Attachable mounting feet can be fitted, as on the fans, and eye-lugs for slinging are provided on silencers of 30 in. diameter and upwards.

Before assembly, all interior surfaces of the silencer casing receive an anti-corrosive coating of a specially formulated red oxide type primer. Exterior surfaces are given a priming coat of red oxide followed by a standard coat of grey alkyd resin paint which affords a durable, weatherproof finish.

General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

Arc-Welding Transformer

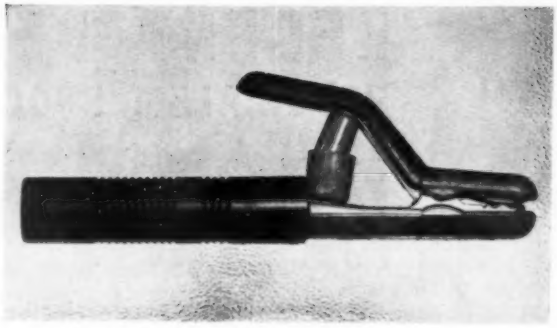
TRANSFORMER model ES.1382 is the newest addition to the Philips range of air-cooled arc-welding plants. It has been designed for production work, and is of robust construction. With an output range of 60–350 amp., the plant has an electrode capacity of 12 s.w.g.—$\frac{5}{16}$ in. diameter, and is, therefore, suitable for production work on light, medium and heavy fabrication, and for general maintenance and repairs. One of the main features is that the welding current is infinitely variable throughout the range. The exact current settings essential for high quality work can therefore be obtained.

Alternative mains connections in the ranges 200–240 or 400–440V. A.C. are provided, and the plant may be connected to single phase supply or between 2 phases of a 3-phase system. No-load consumption of the plant is 300W. Power factor correction can be obtained by installation of a 6-kVA capacitor on the primary side. An open circuit voltage of 75–80 volts is obtained. Adequate cooling is ensured and a red light is fitted to indicate that the transformer is working. Compact in design and mounted on three wheels, the plant's manoeuvrability is increased by castor setting of the single wheel.

Industrial Products Division, Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

New Electrode Holder

AVAILABLE in the United States for some time, the Lincoln-Jackson A-38 heavy duty welding electrode holder is now produced in the United Kingdom and is



available to the welding operator universally. The A-38 is insulated throughout and is made of a 98% copper alloy developed for strength (35 tons/sq. in.), hardness (125 V.P.N.) and conductivity (35% I.A.C.S.). Complete protection from accidental arcing is guaranteed, and the insulated crown channel type jaws make for heat resistivity and durability. The sturdy long handle has been designed to give greater ventilation. An additional important feature is that easily replaceable spare parts can be obtained at moderate prices.

Lincoln Electric Co. Ltd., Welwyn Garden City, Herts.

Thermo-Electric Pneumatic Converter

A NEW feature in Elliott automation is a sensitive converter providing an immediate air output signal on the standard 3–15 lb./sq. in. range, directly proportional to the input signal from thermo-couples or other low D.C. potential sources. Designed for ready assembly into process control panels or incorporation into recorder/controller loops, the converter comprises a chopper unit for rendering the D.C. signal as an A.C. input to a high-gain 3-stage A.C. electronic amplifier, stabilised in respect of mains voltage variation, and operating an Eltair electro-pneumatic unit via a phase-sensitive rectifier.

Provision is included for rapid ' in the field ' conversion to any of five input range spans. There is also provided a D.C. supply, stabilised by a precision neon stabiliser to permit the incorporation of cold junction compensation, range suppression or resistance thermometer operation. A monitoring gauge of robust moving coil construction, scaled in millivolts input and lb./sq. in. output, provides local indication of the operation of the converter.

For process control systems requiring a ready and economic means of recording temperatures, and of furnishing an input source for 2- or 3-term pneumatic control functions, the new Elliott Thermo-Electric Pneumatic Converter provides a compact and versatile general purpose unit.

Elliott Brothers (London), Ltd., Century Works, London, S.E.13.

Birmingham Office Move

THE Birmingham Area Sales Office of Northern Aluminium Co., Ltd., has removed to new and larger premises at 14, Bennetts Hill, Birmingham, 2. From this new address the office will continue, under the managership of Mr. G. A. Vernon, to serve the needs of the Midland counties for all forms of Noral aluminium and aluminium alloy materials. The telephone number, Midland 5236, and telegraphic address, Noralumin Birmingham, remain unchanged.

CURRENT LITERATURE

Book Notices

DIRECTORY OF WELDING AND FABRICATING EQUIPMENT

SECTION I: METAL ARC WELDING ELECTRODES

Published December, 1954, by The Louis Cassier Co., Ltd., Dorset House, Stamford Street, London, S.E.1. Reprinted from *Welding and Metal Fabrication*. Size 11½ × 8¼ in. 35 pages. 3s. 6d. (by post 3s. 9d.).

THIS is the first time that a comprehensive guide to the entire range of electrodes now available in the United Kingdom has ever been published. Engineers may see at a glance details of each British electrode for welding any of the metals at present used in the fabricating industries.

This section of the directory is divided into five parts, dealing with electrodes for arc welding mild steel, alloy steels, cast iron and non-ferrous metals, and for hard-facing. The electrodes are grouped under the names of the respective manufacturers, and the main details are given for each rod, together with any special features. Where the electrodes carry identification markings, such as coloured tips, these are referred to, so that the electrodes can easily be recognised. Recommended welding positions for each electrode are given, and the British Standard Classification numbers, according to B.S. 1719 : 1951, are shown where relevant.

This directory should be very useful to engineers and designers in enabling them to select the most appropriate types of electrodes for their purposes, in shipbuilding, in the motor-car, aircraft, chemical plant, and other industries, for bridge and steel structure building, for casting repairs, and for pressure vessel manufacture, as well as in the lighter industries and small general-purpose welding shops.

ADDENDUM TO INFORMATION BULLETIN NO. 18—ALUMINIUM ALLOY SECTIONS FOR USE MARINE

10 pp., paper cover. The Aluminium Development Association, 33, Grosvenor Street, London, W.1.

THIS little booklet, which presents data additional to that contained in the A.D.A. Information Bulletin No. 18—on Aluminium Alloys Sections for Marine Use—deals with three series of new aluminium alloy sections having particular value in shipbuilding. They are bulb angles for rivetting, and bulb plates and tee-bars for welding. In each case the data comprise an outline of the section with dimensions and properties. A brief account of the basis and development of these sections includes a note on the aluminium alloy in which they will, in general, be made.

KEMPE'S ENGINEER'S YEAR BOOK

3,000 pp. (in two volumes), crown 8vo. 28, Essex Street, London, W.C.2. 75s. (by post 77s. 6d.).

THE 1955 Edition of Kempe's Engineer's Year Book is the 60th since it was first published in 1894, and in spite of the fact that the 1954 Edition was completely re-written, with the introduction of eight new chapters, there have been further additions this year on certain topics. For instance, further information on shell moulding is given in the chapter on Foundry Practice: about geared couplings in that on Shafts and Couplings: and about preparing rolls in the chapter on Forging Hammers and Drop Forging Plant. Additions have also been made in the chapters on Electronic Engineering, Explosives, and Flow Metering and Mechanical Testing. With the object of making the Year Book easier to use, the number of cross references to the text has been increased and there are now 124 pages of index which it is hoped will ensure easy access to the desired information.

Trade Publications

DURING post-war years, development work has led to a whole range of new materials for building construction and cladding, many of them untried by hard experience, and each challenging the next for the lead in acceptance as a durable and economic product. Aluminium, although by no means new to the building industry, was restricted in its pre-war uses by lack of knowledge of its durability, and by its high price relative to other materials. In a booklet published by Northern Aluminium Co., Ltd., Banbury, entitled "The Durability of Aluminium in Building," is outlined some of the long-term experimental work carried out in America, with the evidence of an ever-growing number of highly successful practical applications in the United Kingdom and abroad, which are together showing that aluminium has a durability which makes it, in terms of economic life, one of the cheapest of all permanent building materials.

INSPECTION enlargers and production projectors are featured in two new brochures issued by Hilger and Watts, Ltd., 98, St. Pancras Way, Camden Road, London, N.W.1. The former are designed to fulfil all the requirements for simple comparison of the image with an enlarged template, and they are robust enough for use in the workshop as well as in the inspection department. Provision is made for examining surfaces as well as profiles. The production projectors are designed for the rapid routine gauging, by projection in relation to templates, of large numbers of objects of the same kind, whose handling can be accelerated by holding devices specially suited to them. One model described has a micrometer workstage.

A SPECIAL patented process has been introduced by Henry Wiggin & Co., Ltd., which has resulted in the production of an insulating coating on Brightray B. This is a nickel-chromium-iron alloy with a high specific electrical resistance, but the oxide normally formed has low insulation properties and this material cannot, therefore, be used for close-wound resistances. To produce oxy-insulated Brightray B the wire is first plated with nickel which is subsequently oxidised. A recently issued leaflet includes data on this form of Brightray B and illustrates typical applications. Copies can be obtained from the Publications Department of the Company at Thames House, Millbank, London, S.W.1.

THE Gas Council has published a completely new and revised edition of the popular brochure, "Gas in Industry," which describes and illustrates some of the

more important of the four thousand industrial processes in which gas is used. The amount of gas used by industry has increased by two-thirds since the end of the war, and industrial sales now account for a quarter of the total sales of gas throughout the country. The use of gas for heat treatment processes assists in the achievement of accurate control of temperature, automatic control being available in most cases if desired; a high standard of quality in the product and a minimum of spoilage; clean and healthy working conditions; a saving in labour costs and in the necessity for fuel storage; and more rapid production. Among the industries specially featured in this booklet are steel and other metal trades, glass manufacture, core drying, printing, chemicals, wiremaking, baking, food manufacture, pottery manufacture, and paints, oils and varnishes.

THE latest issue of *Wiggin Nickel Alloys* (No. 30) contains a number of articles on equipment or processes in which nickel alloys play a part. Of particular interest is an article on cutting fluids for use in machining the Nimonic alloys which have played such an important part in the development of the gas turbine, and which have presented considerable difficulties to the machinist. A further article describes the production of centrifugal and shell-moulded castings by the Sheepbridge Company, well-known for many years as pioneers in centrifugal casting. Other features deal with detergent manufacture, temperature measurement, engine valves, water softening, railway electrification, and pickling baskets and brine pumps. Copies may be obtained from Henry Wiggin & Co., Ltd. Wiggin Street, Birmingham, 16.

WE have received from The Incandescent Heat Co., Ltd., Smethwick, their latest leaflet (No. V15) which deals with Incandescent Hi-Nitrogen Generators, which are self-contained combustion method units for the low-coast production of nitrogen from a mixture of air and any fuel gas. The fuel and air are burnt in a combustion chamber and the bulk of the moisture condensed out before absorption of the CO_2 in monoethanolamine. Passage through an activated alumina dryer removes the last traces of water vapour. An air-gas carburettor is provided which can be adjusted to give a product ranging from 99% pure nitrogen up to a mixture containing either excess oxygen or excess combustibles, as required, up to about 6%.

SINCE the British coal industry was nationalised, the National Coal Board have planned the building of a series of comprehensive coal carbonising plants on new sites. Fishburn is the first of these plants to be built and put into operation, and the main contractors for the project—Woodall-Duckham Construction Co., Ltd. Brompton Road, London, S.W.3.—have recently published a beautifully illustrated brochure describing the plant. It consists of 50 W.-D. Becker Combination Underjet Ovens capable of carbonising 1,000 tons of wet coal per day; a coal handling, blending and crushing plant; a coke handling and screening plant; a by-product recovery plant of the semi-direct type; a crude benzole plant; a water cooling and recirculation system; and extensive railway sidings.

"METALLURGICAL MICROSCOPES" is the title of a new publication by W. Watson & Sons, Ltd., 313 High Holborn, London, W.C.1. The "Research" microscope is available as a monocular, binocular, or combined monocular-binocular instrument. To eliminate loss of light by reflection, all prisms and correcting lenses employed in the body are coated and special treatment is given to the optical system of the illuminator. The "Standard" microscope is available only as a monocular instrument. Separate catalogues are available for the Holophot photomicrographic equipment for metallurgy and also for the photomicrographic cameras, but the present booklet gives particulars of a number of accessories, including a specimen polishing machine.

ALUMINOUS castable refractories have been used successfully for a number of years for making special shapes and forming monolithic linings, but although they have many desirable properties they are not particularly resistant to the action of slag. General Refractories have recently issued a leaflet describing their Pyrocrete basic refractory concretes which have been designed to offer the advantages of aluminous castable refractories together with good resistance to slag attack. Four grades are described—with chrome, chrome-magnesite, magnesite-chrome, and magnesite bases—and details are given of their mixing, application and drying.

STEEL and bronze specifications are featured in a new handy-sized pocket book published on behalf of the Foundry Group companies of The David Brown Corporation (Sales), Ltd. Details are given of various materials in general production in the Foundries and Jackson Divisions. The latter's production is confined to carbon and low alloy steels, but the Foundries Division handles also a number of special steels: some for use at sub-zero temperatures, some at elevated temperatures, and others in corrosive environments. The well-known Taurus bronzes are also cast at the Penistone works.

DETAILS of the complete range of Metrovick arc welding electrodes are given in new thumb-indexed pocket electrode guide. They include rods for welding mild and high tensile steels, corrosion resisting steels, creep resisting steels, and cast iron, together with a range of hard surfacing electrodes. The particulars given include the approvals received from various bodies; the applications for which the rod is suitable; the operating technique; the electrical supply necessary; analysis and mechanical properties of deposit; and packing details.

Books Received

"Catalysts, Special Compounds and Chemical-Resistant Materials." General Editor: E. Molloy. Advisory Editor: E. Carr. 222 pp. inc. index. London, 1955. George Newnes, Ltd. 21s. net.

"Analysis of Deformation," Volume II: "Experiment and Applied Theory." By Dr. Keith Swainger. 365 pp. inc. index. London, 1954. Chapman and Hall, Ltd. 70s. net.

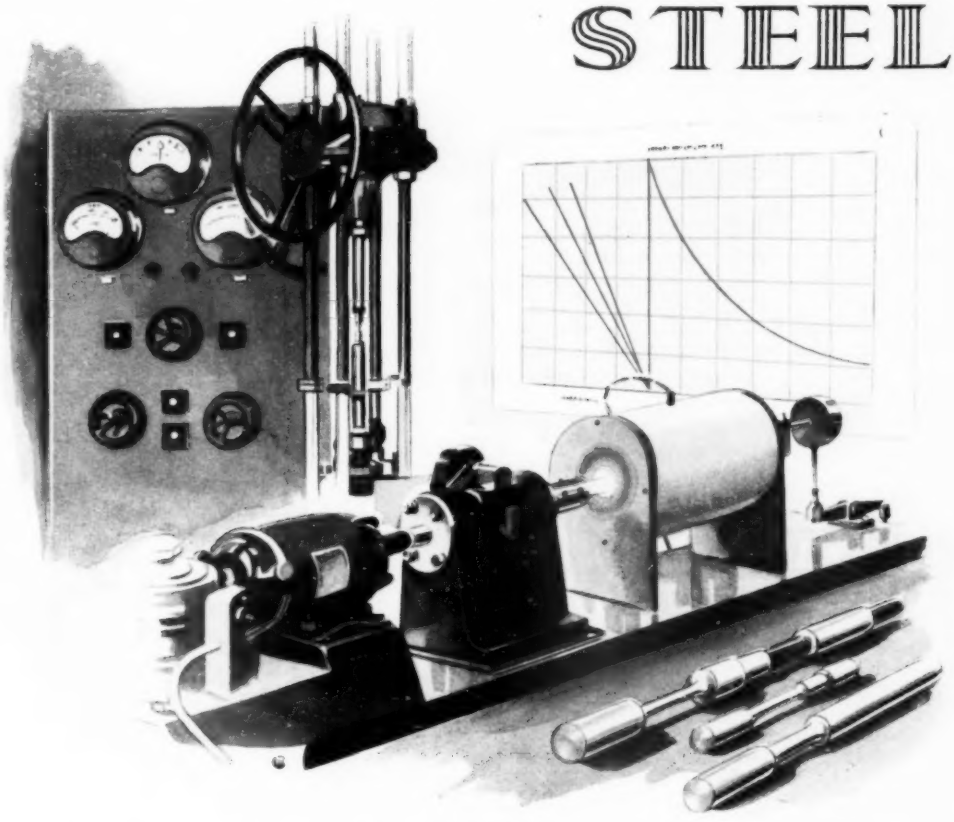
"Welding for Engineers." By Harry Udin, Edward R. Funk and John Wulff. 430 pp. inc. index. New York and London, 1954. John Wiley & Sons, Inc., and Chapman and Hall, Ltd. 60s. net.

"Elektrolytische Abscheidung und Elektrokristallisation von Metallen." By Dr. Hellmuth Fischer. 717 pp. inc. index and 247 illustrations. Berlin, Göttingen and Heidelberg, 1954. Springer-Verlag. Ganzleinen DM 72.

"Physical Chemistry and Metal Extraction," by D. W. Hopkins. 232 pp. inc. author and subject indexes. London, 1954. J. Garnet Miller, Ltd. 30s. net.

*Formula for*_____

STEEL



This is the seventh in a series of illustrations of highly specialised equipment devised to control the production and testing of special steels by

William Jessop & Sons Ltd.

When a metal is subjected to repeated stressing it will fail at a lower stress than it is capable of enduring under static conditions, and this phenomenon is known as "fatigue". By careful study of the effect of repeated stresses in tension and compression, or in bending, the metallurgist is able to say what stresses his products will endure under these exacting conditions. Tests of more than 100,000,000 stress reversals taking 14 days are carried out.

Fatigue conditions occur in such widely divergent applications as suspension bridges, the moving parts of reciprocating engines, the simple chisel, and the gas turbine. In the case of the gas turbine, the conditions are even more onerous as not only is the metal being dynamically stressed but it is also red hot and hence a knowledge of the safe stress or fatigue limit over the whole range of useful temperatures for the alloy is essential.

A new high temperature alloy for gas turbine blades may require a total of 50 tests at about half a dozen different temperatures taking 500 machine-days of testing time. The problem is, however, so important in modern engineering that such data is being extensively obtained.

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'Crystallex' X-Ray Film
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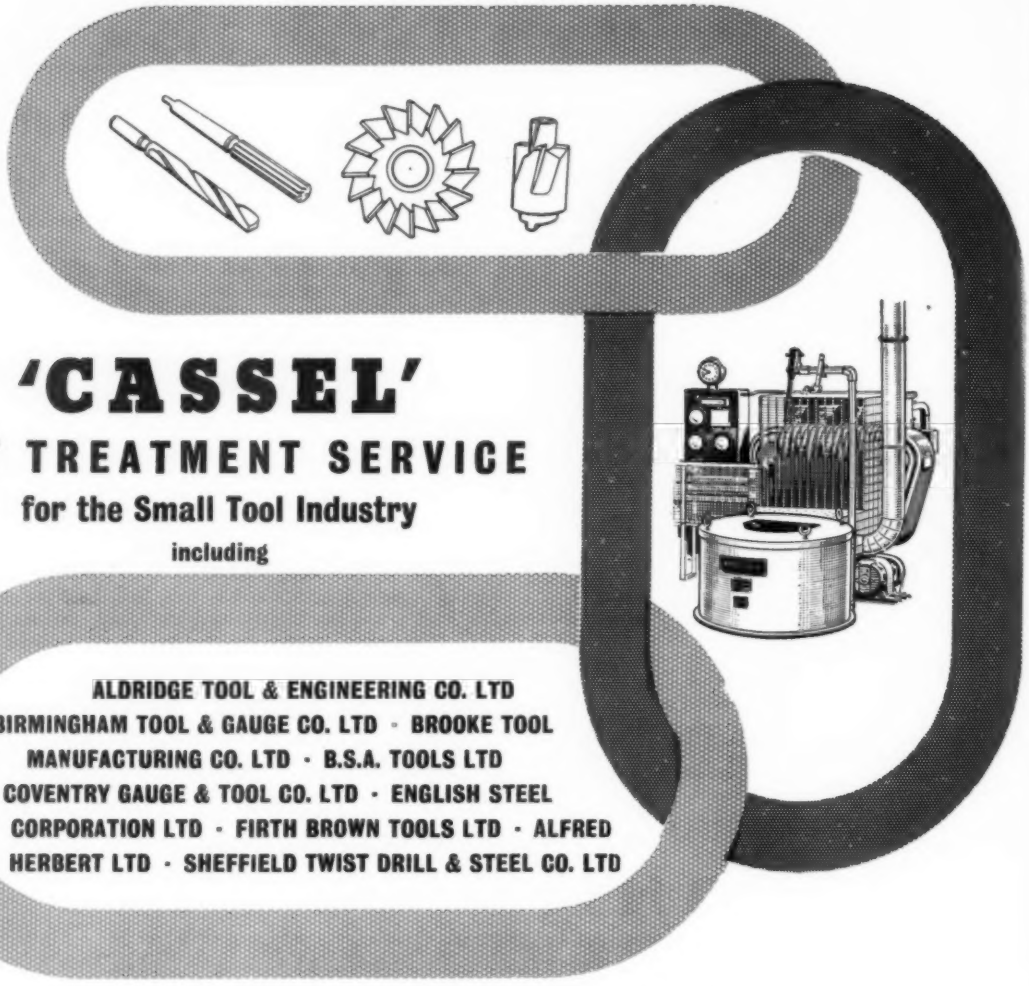
The remote Control Unit combines safety with ease of operation, while the choice of Single-column or Gantry Tubestand renders the apparatus suitable for radiography of a wide variety of components.

IX 7



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C.C.166

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
FEBRUARY, 1955 Vol. LI, No. 304

Industrial Applications of Infra-Red Gas Analysis

By J. O. Lay, F.R.I.C.
British Iron and Steel Research Association

A wide range of compound gases can be detected and evaluated in gaseous mixtures by measurement of their infra-red absorption characteristics. Suitable equipment, in which the sensitivity can be adjusted to cover the range 0–100% and the interference of other constituents can be avoided, is described and methods for the determination of more than one component are mentioned.

Introduction

INDUSTRIAL atmospheres vary widely in composition, quite apart from their burden of air-borne solid particles, and in many commercial applications control of gas concentrations, both in natural and artificial mixtures, is required. It is frequently desirable for an accurate knowledge of the constituents of a particular gaseous mixture to be available, either instantaneously or over a period, particularly if control of the ratio of the components is necessary, or if safeguards against extraneous contamination need to be introduced.

As examples of the circumstances in which such information may be of value, safety in mines, fuel combustion, and metallurgical heat-treatment may be cited. In mines or other underground workings, adequate ventilation and freedom from noxious or inflammable vapours assist in the efficiency of operation, and obviate the need for inconvenient precautionary measures such as respirators. A guarantee of the completeness of combustion or information about the combustion products can be of considerable interest to the fuel engineer and can ensure the most economic utilisation of the fuel. For the metallurgist, the freedom of a heat-treatment atmosphere from deleterious components, such as oxides of carbon and sulphur, water vapour or nitrogenous compounds, according to circumstances, is of paramount importance, while the evolution of cyanogen from cyanide baths affords a further example of the need for control.

It is, therefore, evident that a simple method of analysing and, if possible, of controlling gaseous mixtures can meet existing demands in a variety of industries, and is likely to command a fairly extensive market.

Theoretical Considerations

Infra-red radiation, like visible and ultra-violet light, is composed of rays of various wavelengths. When such radiation is passed through a compound gas, rays of specific wavelengths are absorbed and the temperature of the gas rises; this property can therefore be made use of in identifying the constituents, and in determining the composition of gaseous mixtures (Table I).

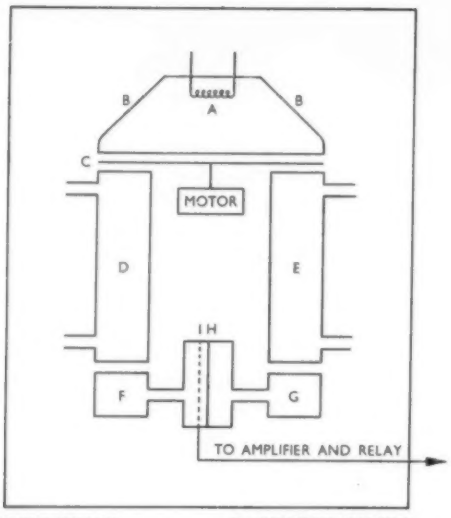
For example, a 'standard' atmosphere, containing only simple gases (oxygen, nitrogen, hydrogen, argon, chlorine *et al.*) which have little inhibiting effect, can be employed and the total intensity of radiation (heat) in specific wavelengths emitted from an infra-red source can be measured after passing through the 'standard' gas by its effect on the gas being investigated, e.g., carbon dioxide, contained in a closed chamber. Introduction of a known volume of carbon dioxide into the 'standard' atmosphere will cause a diminution in the emergent radiation, again in the specific wavelengths already mentioned, which will be indicated by the behaviour of the gas in the target chamber and (at low concentration) will be in proportion to the amount of impurity added.

TABLE I.—TYPICAL INFRA-RED ABSORPTION WAVELENGTHS.

Compound	Formula	Approximate Absorption Wavelengths (μ)					
Methane	CH_4	7·7					
Acetylene	C_2H_2	7·4	7·7	13·3			
Ethylene	C_2H_4	5·3	6·9	10·1	10·5	11·0	11·8
Ethane	C_2H_6	6·8	7·5	11·9	12·2	12·5	13·2
Cyanogen	CN	4·7	13·5	16·1			
Carbon Monoxide	CO	4·7					
Carbon Dioxide	CO_2	4·2	4·3	14·7	15·1		
Hydrochloric Acid	HCl	80·0	120·4				
Hydrocyanic Acid	HCN	7·0	7·2	13·6	14·3		
Hydrofluoric Acid	HF	48·9	61·2	121·1			
Water	H_2O	6·8	28·4				
Hydrogen Sulphide	H_2S	8·8	9·6	10·1	10·6	10·9	
Ammonia	NH_3	6·1	10·3	10·7	15·9	17·1	
Nitric Oxide	NO	5·3					
Nitrogen Dioxide	NO_2	6·1	7·3	15·6			
Nitrous Oxide	N_2O	5·4	5·5	7·8	8·6	16·9	17·3
Nitrogen Trioxide	N_2O_3	5·7	7·9	10·6	11·3	13·3	
Nitrogen Pentoxide	N_2O_5	4·8	5·8	7·6	11·4		
Sulphur Dioxide	SO_2	4·4	5·7	7·4	8·7	16·5	19·1

It is evident that any overlap in absorption wavelengths, as occurs with some gaseous organic compounds, will interfere with the accuracy of the determination if more than one of the gases is present in the mixture, but this difficulty can be overcome by using a filter which is opaque to the coincident absorption wavelengths, e.g., a chamber filled with the unwanted gas. By contrast, the detection chamber can be filled with mixed gases and a determination of their combined proportion in the sample under examination can be made; this is of most value when the absorption constants of the gases are similar.

Using a small gas concentration c in a column of length l, the energy absorbed is $Ekcl$, where E is the incident energy and k is the absorption constant of the



A—INFRA-RED SOURCE
B—REFLECTORS
C—ROTATING VANE
D—' STANDARD ' GAS CHAMBER
E—' SAMPLE ' GAS CHAMBER
F—DETECTOR CHAMBER
G—DETECTOR CHAMBER
H—METAL DIAPHRAGM
I—PERFORATED METAL PLATE

Fig. 1.—Diagram of infra-red detector unit.

gas. Considerable deviation from this simple relationship occurs when kcl exceeds 25%, and it is then necessary to reduce l in order that cl may remain approximately constant.

Equipment Required

A diagrammatic representation of commercially produced equipment is given in Fig. 1. A heated nickel-chromium wire A is the source of infra-red radiation, which is collected by the reflectors B and is allowed, by the rotating vane C, to pass intermittently and simultaneously through the chambers D and E, filled respectively with the ' standard ' and ' sample ' atmospheres. The unabsorbed radiation impinges on the measuring chambers F and G, filled with the gas being detected, any difference between the two sides causing dilation of the thin metal diaphragm H. The latter, together with the perforated metal plate I, forms an ' air ' condenser, the pulsating change in the capacity of which provides information about the concentration of the absorbing gas in the ' sample ' atmosphere.

It has been found that water vapour and carbon dioxide have a slight effect in reducing the passage of radiation when other gases are being determined, and the interposition of chemical absorbents is desirable in such cases; it is also advisable to remove entrained dust from the gas sample. Chemical treatment offers an alternative means of removing other gases which exhibit interfering absorption characteristics.

The speed of response depends upon the rate of flow of gas and the sensitivity of the output circuit; it can be as low as a few seconds. The gas chambers consist of metal tubes capped with mica, infra-red transmitting glass, fluorite or other suitable material, and can be used in varying lengths to permit the introduction of filters, extra sample chambers and similar aids to detection; they can generally be evacuated and/or sealed if required, although mica windows will only stand a moderate pressure ($\frac{1}{2}$ atm.).

Stability in the electrical supply improves the operation of the detector, although minor fluctuations have little effect on its accuracy. A wide range of gases can be detected at concentrations from 0·001% upwards by varying the sensitivity of the assembly, either by electrical or wave-path adjustments. Temperature variations are almost without effect, apart from their influence on the gas concentration, except in the determination of water vapour; in this case the use of a thermostat may be desirable.

When adjusted for automatic operation, chambers of different lengths may be included in the wave-path and the flow of gas diverted to the appropriate chamber to obtain the required sensitivity, provided that the total length of the ' sample ' assembly remains equal to that of the ' standard ' and that unused chambers are filled with the ' standard ' atmosphere. In this way large variations in composition can be accommodated without difficulty.

Operating Details.

In order to demonstrate conveniently the operation of the equipment, suppose that the concentration of a gas X (e.g., carbon dioxide) has to be determined continuously in a furnace chimney, and that variations from under 1% to about 30% may be encountered according to the conditions in the furnace (it may, of course, be desirable to use the detector as a means of maintaining optimum conditions, e.g., by controlling the air supply to the furnace, but this extension of its use will be mentioned later). The sample analysis side of the apparatus can then be arranged as indicated diagrammatically in Fig. 2, which permits a tenfold increase in sensitivity to be obtained when the impurity concentration falls to the lower levels. When not in use for high-sensitivity measurements the longer section P of the chamber is filled with dry, carbon-dioxide-free gas to correspond with the ' standard ' atmosphere.

The change in sensitivity can be operated automatically by using the amplified signal from the condenser to rotate the change-over taps (T_1 and T_2) mechanically; other sensitivity ratios can be obtained by similar means or, alternatively, a three-section chamber may be employed to extend the range even further, e.g., for ratios of 1 : 5 : 25. Furthermore, by suitable application of the amplified condenser response a pen-recorder can be operated, electronic switching devices can be used to control the fuel or air intake, visual or audible signals relating to composition can be provided, or other necessary operational adjustments can be made.

Mains A.C. supply through a constant voltage transformer is normally adequate for the electrical requirements of the instrument, although a voltage stabiliser may be desirable for very precise work. No serious difficulties arise in the use of a D.C. mains or battery supply for the apparatus, only slight modifications in wiring or the provision of a rotary converter being necessary for the change-over. Apart from the electrical supply, the model can be made entirely portable if only simple recording is required.

Standardisation

Reference to the theory of operation of the equipment will indicate that a straight line relationship should hold over a range of concentration of the measured gas X in the sample. It is, however, necessary to confirm the extent of this relationship under similar circumstances

to those in which the gas concentration will be determined. The simple standardisation procedure is therefore as follows :—

1. Set the zero of the recording or controlling device with both ' standard ' and ' sample ' chambers filled with the appropriate ' standard ' atmosphere.
2. Introduce synthetic atmospheres containing small increments of gas *X* and plot the change in emitted radiation until deviation from a straight line graph is evident.
3. Alter the sensitivity by electrical means or by the method described in the preceding section.
4. Continue the calibration until the required range of concentration is covered.

Controlling devices can, of course, be pre-set to operate at a known concentration of the gas being estimated, while recording charts or dials can be marked to read in percentage composition, gas ratio or other relationship as desired. It must be clearly understood, however, that any major change in conditions of operation may make re-standardisation desirable, even though the principle of the method renders it unlikely that serious error in measurement can occur.

As most units would be built for use in a particular set of circumstances, the potential drawback of frequent standardisation is not of great consequence in routine applications, and would in any case be a normal safeguard in any research investigation.

Applications

Mining. Concentrations of methane or carbon monoxide gas present serious hazards in coal mining ; the former is normally removed by drainage from the source of flow and subsequent collection, owing to its commercial value, but both can be diluted or swept away by free ventilation. There are thus two specific uses for the infra-red detection unit here ; firstly, in ensuring a sufficiently high concentration of methane in the gas collected by drainage for it to be of industrial importance, and, secondly, in confirming that ventilation keeps the impurity content of mine air below the danger level. Similar considerations apply in relation to concentrations of carbon dioxide in shafts or other underground workings. By incorporating signals or automatic controls in the detector mechanism, virtually continuous analysis can be achieved and rapid adjustment can be made as required.

Fuel Control. Several aspects of combustion can be controlled in the interests of efficiency ; e.g., the adequate proportioning and mixing of gaseous and atomised liquid fuels with air, the adjustment of composition of the combustion products, and, where necessary, the elimination of corrosive constituents.

Continuous monitoring of these variables or periodic tests, associated with suitable control or inspection schedules, can be devised on the basis of the infra-red detector equipment, and such components as carbon monoxide, carbon dioxide and sulphur dioxide evaluated.

Metallurgy. Similar considerations to those mentioned above must be taken into account in many aspects of metallurgical processing and heat treatment. Annealing atmospheres may need to be free of oxygen, among other constituents, and detection of this gas can be achieved, although it does not itself absorb infra-red radiation, by mixing the dry furnace gas with hydrogen (if necessary), passing over a platinum catalyst and determining the water vapour produced. Hydrogen concentrations can

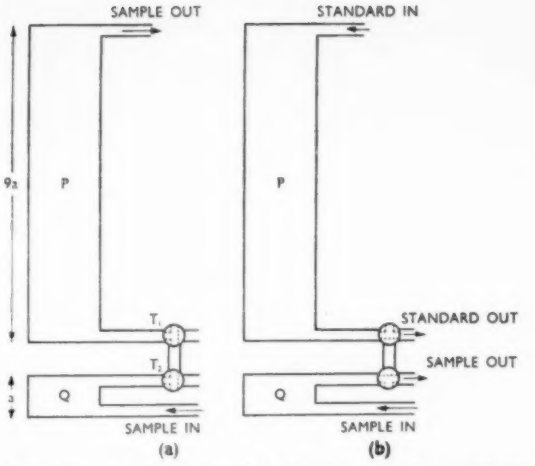


Fig. 2.—Two section chamber for increased sensitivity: (a) high sensitivity setting ; (b) low sensitivity setting.

be measured in a corresponding manner and, of course, unchanged ammonia in cracked ammonia gas can conveniently be detected by direct examination.

A further important application is in the examination of the atmosphere in the neighbourhood of cyanide or mixed-salt heat-treatment baths, and of silver (cyanide) and other plating processes. Factory regulations require free ventilation and the removal of toxic gases, which can be confirmed by the use of the infra-red detector unit.

Vacuum Techniques. Vacuum and pressure vessels or chambers must be gas-tight, and it is, therefore, of the utmost importance to be able to locate perforations or weaknesses speedily, without the difficulty and danger of a full scale trial. Leaks can be quickly located in large containers by introducing a gas such as nitrous oxide, raising the internal pressure and using a flexible search tube attached to the detector unit, with a small suction pump to draw air through the apparatus. Such low concentrations of nitrous oxide can be detected that any emission from the container can be readily observed. The reverse of this technique has other applications, e.g., to confirm the efficiency of a ventilating system, where nitrous oxide is injected and the rapidity of its disappearance recorded.

Drying Processes. Because of its sensitivity to water vapour, a possible application of the detector unit is in the field of moisture control. Other methods are, of course, available for this purpose, but the detector certainly affords a convenient means of controlling humidity, measuring drying rates, and examining water evolution in general. In the processing of textiles, for instance, relative humidity affects colour and texture; in the production of electrical equipment removal of condensed moisture is essential prior to varnish impregnation; and in agricultural and biochemical research a knowledge of water needs and intake provides information about conditions of growth.

Chemical Analysis. In the determination of carbon and sulphur in steel, combustion of the sample followed by gravimetric or volumetric measurement of the resultant oxides is normally employed. If, however, the combustion gases are collected in a pre-determined volume, the concentration of these oxides can be found by means of the detector unit and the proportion of the

corresponding elements in the steel obtained by calculation. A possible alternative worthy of exploration would be a device to permit cumulative recording of the impurity content of a steady gas flow, but this refinement is unlikely to be practicable.

Organic Compounds. Many common organic compounds absorb radiation in the lower wavelengths (below 5μ), but filters (e.g., chambers filled with the unwanted gas) can be employed to remove these wave lengths. Without this precaution, however, the detector unit can be used for the identification and measurement of such compounds as acetones, the higher alcohols and benzene derivatives in ordinary atmospheres, but with it the unit can be adapted to select a specific compound from gaseous organic mixtures. This characteristic can be employed for operational control in industrial solvent recovery or extraction plants.

Gas Mixtures. Reference has been made earlier to the use of the detector unit for measuring gas flow and the composition of mixtures. Many applications of this type which cannot be dealt with in detail arise in the fields of sociology, industry and research; examples which may be mentioned are in assessing the operation of submarine equipment, in investigating waste gas recovery, and in the discovery and treatment of allergies. Few occasions where a gas or vapour is being handled can arise in which the use of an infra-red detector unit does not offer a simple and satisfactory means of evaluation and control.

Conclusion

The infra-red absorption characteristic of any compound gas provides a measure of its concentration in a gaseous mixture. Measurement of the heat loss at appropriate wavelengths resulting from the passage of infra-red radiation through the mixture can be related directly to the proportion of any specific compound present.

Filters, generally consisting of chambers containing an interfering gas, can be used to remove unwanted radiation, sensitivity can be adjusted by suitable dilution of the sample or amplification of the response and chemical reactions can be employed to convert non-absorbent simple gases to compounds which can be determined by their infra-red absorption.

Possible applications of the infra-red gas measuring technique arise in almost every field of industry, the results of which can be employed for recording or controlling operations, and only minor modifications of commercial equipment are likely to be required for a very considerable extension of the usefulness of this simple procedure.

While it may be argued that certain of its functions can equally well be performed by less expensive or more familiar equipment, the ease with which its operation can be adapted to widely diverse problems and to a considerable range of gas compositions gives it a unique place among apparatus designed for the purposes of gas and vapour identification and control.

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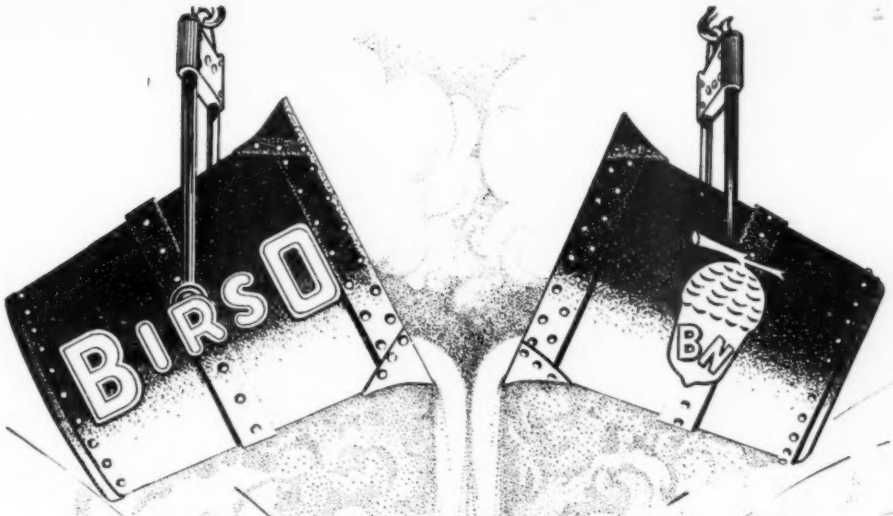

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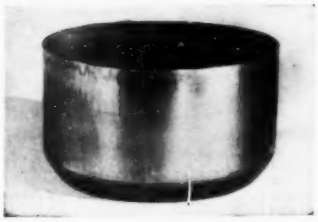

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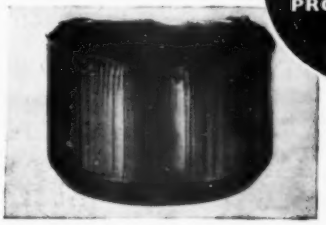

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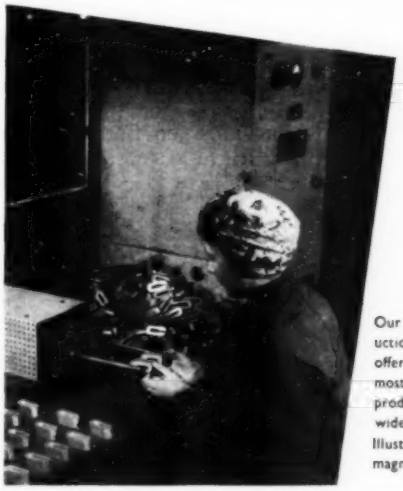

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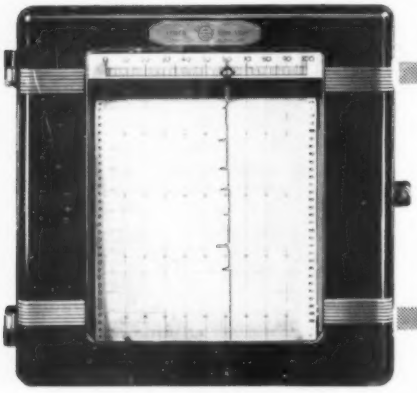

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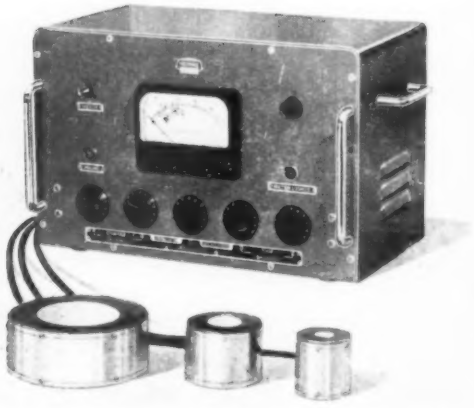

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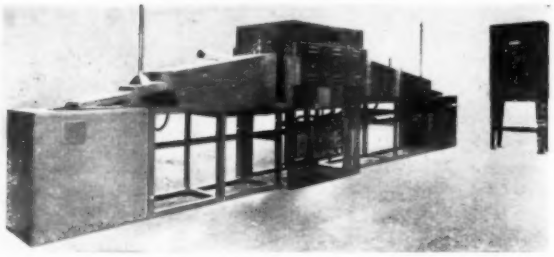

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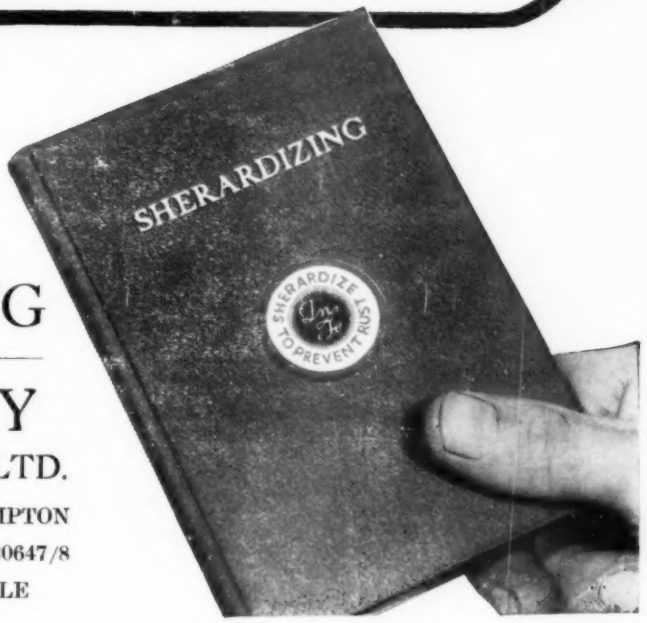

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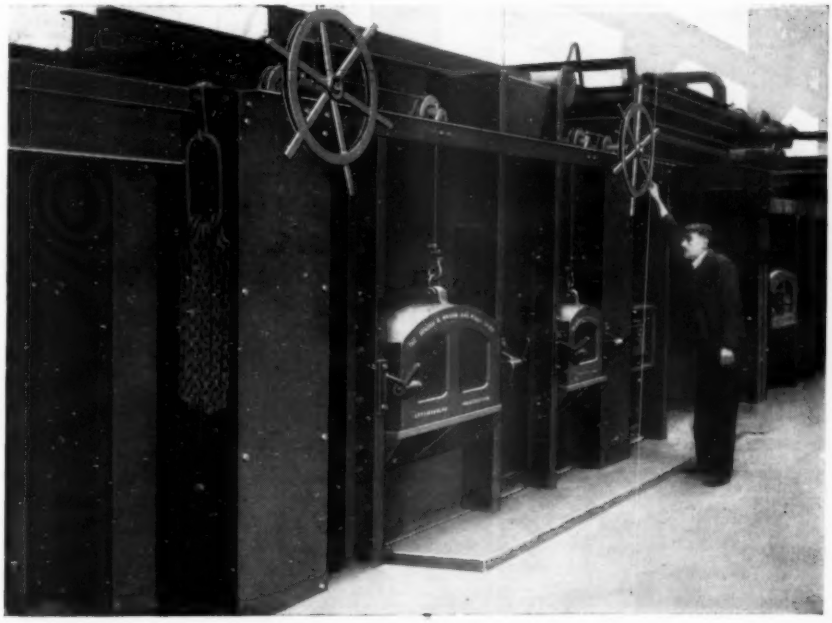

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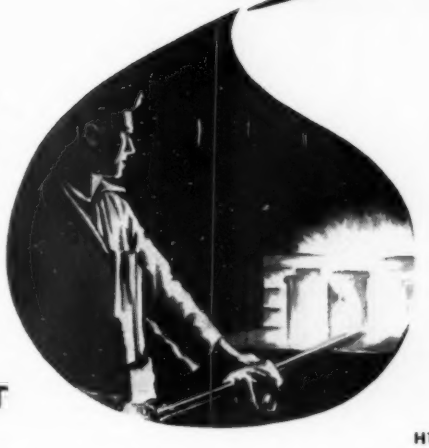

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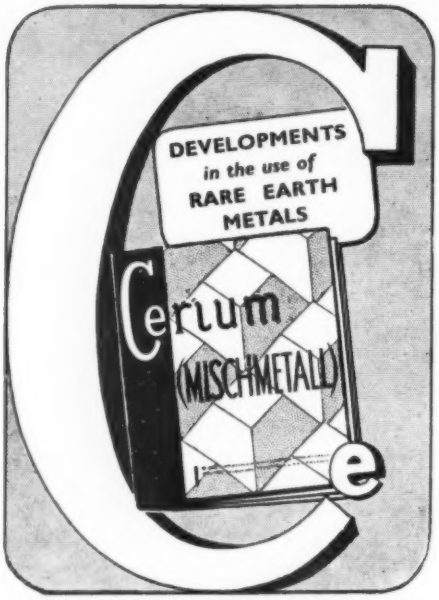

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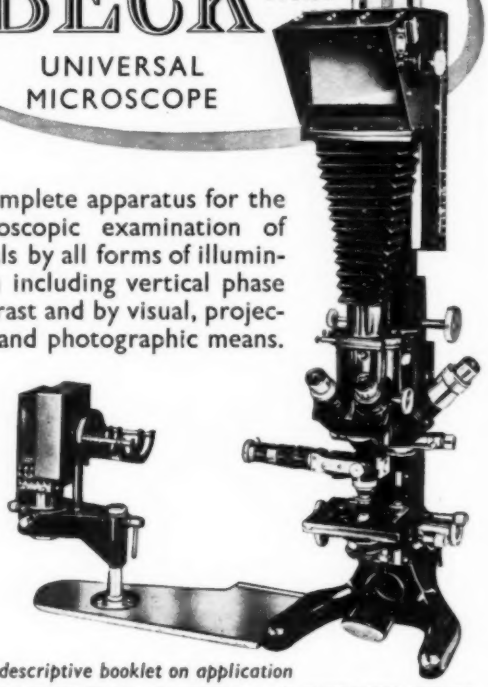

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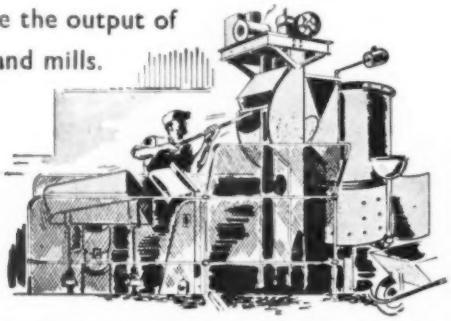

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Further information and application forms are obtainable from the South African Scientific Liaison Officer, Africa House, Kingsway, London W.C.2.

Applications, giving full details of age, marital status, qualifications, experience and the names of referees, must reach the Secretary/Treasurer, C.S.I.R., P.O. Box 395, Pretoria, South Africa, before March 15th, 1955. A copy of the application must be sent to the South African Liaison Officer in London.

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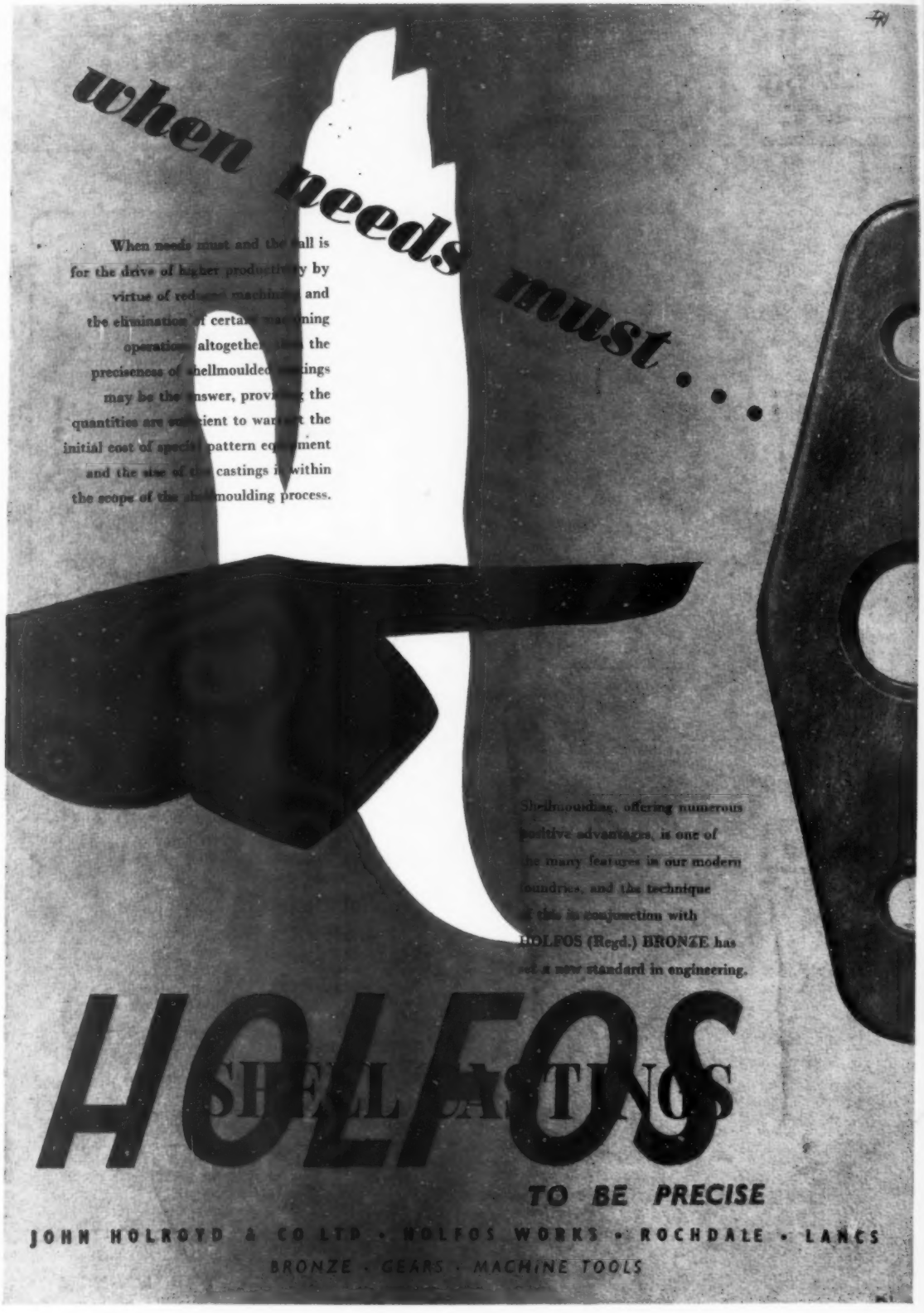
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